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Economic Prefeasibility Studies of Mining in the Koyukuk Mining District, Northern Alaska

James R. Coldwell

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Author

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Cover Photos

(Left) Placer mining operation on Jay Creek, Northern Lights Mining, Inc. (1988), (upper right) placer mining operation on Nolan Creek, Silverado Gold Mines, Inc. (1994), photos by Joseph Kurtak; (lower right) portal of underground drift mine on Mary's Bench near Nolan Creek, Silverado Gold Mines, Inc. (1998). Photo by Karsten Eden.

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

bcy	bank cubic yards
dpy	days per year
klcy	thousand loose cubic yards
kst	thousand short tons
lb(s)	pound(s)
lcy	loose cubic yards
lcy/d	loose cubic yards per day
mi	miles
Mst	million short tons
st	short tons
stpd	short tons per day
stpy	short tons per year
tr oz	troy ounces
yrs	years

ACRONYMS AND ABBREVIATIONS

AACE	American Association of Cost Engineers (AACE)
ACRS	Accelerated Cost Recovery System
AMICEF	Alaska Mineral Industry Cost Escalation Factors
ANCSA	Alaska Native Claims Settlement Act
ANILCA	Alaska National Interest Lands Conservation Act
APMA	Annual Placer Mining Application
BLM	Bureau of Land Management
CES	Cost Estimating System
DCFROR	Discounted Cash Flow Rate of Return
FEIS	Final Environmental Impact Statement
GIPV	Gross In Place Value
LHD	load-haul-dump
MAS	Minerals Availability System
MINFILE	British Columbia Geological Survey mineral database
RMV	Recoverable Metal Value
U/G	underground
USBM	U.S. Bureau of Mines
USGS	U.S. Geological Survey

ECONOMIC PREFEASIBILITY STUDIES OF MINING IN THE KOYUKUK MINING DISTRICT, NORTHERN ALASKA

by James R. Coldwell[1]

ABSTRACT

Mining and processing cost analyses were conducted on nine mineral development scenarios for the Koyukuk Mining District study. The district is located on the upper portion of the Koyukuk River basin. Resources and recoverable metal values (RMV) needed to make these deposits yield a 15% Discounted Cash-Flow Rate-Of-Return (DCFROR) were modeled.

Economic modeling for surface-mined placer gold deposits indicated the RMV ranged from $18.43 per loose cubic yard (lcy) for a 243 loose cubic yards per day (lcy/d) operation to $4.23/lcy for a 1,941 lcy/d operation supported by a 10-mile (mi) road. The RMV ranged from $25.49/lcy for a 243 lcy/d operation to $4.84/lcy for a 1,941 lcy/d operation supported by a 50 mi road. The RMV ranged from $35.05/lcy for a 243 lcy/d operation to $5.63/lcy for a 1,941 lcy/d operation supported by a 100 mi road. The RMV ranged from $18.35/lcy for a 243 lcy/d operation to $4.62/lcy for a 1,941 lcy/d air supported operation approximately 200 mi from Fairbanks.

Modeling for surface-mined placer gold deposits indicated the RMV ranged from $16.82/lcy for a 243 lcy/d operation to $4.11/lcy for a 1,941 lcy/d operation supported by a 10 mi winter trail. The RMV ranged from $17.61/lcy for a 243 lcy/d operation to $4.18/lcy for a 1,941 lcy/d operation supported by a 50 mi winter trail. The RMV ranged from $18.55/lcy for a 243 lcy/d operation to $4.30/lcy for a 1,941 lcy/d operation supported by a 100 mi winter trail.

Modeling for underground-mined placer gold deposits indicated the RMV ranged from $19.73/lcy for a 243 lcy/d operation to $6.41/lcy for a 1,941 lcy/d operation supported by a 10 mi road. The RMV ranged from $26.82/lcy for a 243 lcy/d operation to $7.04/lcy for a 1,941 lcy/d operation supported by a 50 mi road. The RMV ranged from $36.04/lcy for a 243 lcy/d operation to $7.82/lcy for a 1,941 lcy/d operation supported by a 100 mi road. The RMV ranged from $18.19/lcy for a 243 lcy/d operation to $6.33/lcy for a 1,941 lcy/d air supported operation approximately 200 mi from Fairbanks.

Modeling for underground-mined placer gold deposits indicated the RMV ranged from $18.19/lcy for a 243 lcy/d operation to $6.28/lcy for a 1,941 lcy/d operation supported by a 10 mi winter trail. RMV ranged from $18.86/lcy for a 243 lcy/d operation to $6.37/lcy for a 1,941 lcy/d operation supported by a 50 mi winter trail. The RMV ranged from $19.99/lcy for a 243 lcy/d operation to $6.51/lcy for a 1,941 lcy/d operation supported by a 100 mi winter trail.

Modeling indicated that for an increment in RMV ranging from $2.18/lcy for a 243 lcy/d operation to $0.25/lcy for a 1,941 lcy/d operation, a backhoe and laborer can be added to the gold placer mine models.

Modeling for copper porphyry deposits indicated the RMV ranged from $90 per short ton (st) for a 3,913 short tons per day (stpd) operation to $37/st for a 31,309 stpd operation.

Modeling for copper skarn underground mines indicated the RMV ranged from $561/st for a 114 stpd operation to $299/st for a 912 stpd operation. Economic modeling for copper skarn surface mines indicated the RMV ranged from $455/st for a 114 stpd operation to $242/st for a 912 stpd operation.

Modeling for mineralized quartz vein deposits indicated the RMV ranged from $2,688/st for a 4 stpd operation to $538/st for a 36 stpd operation with an on-site mill. The RMV ranged from $1,596/st for a 4 stpd operation to $502/st for a 36 stpd operation which shipped ore directly to a smelter.

Modeling for massive sulfide deposits indicated the RMV ranged from $832/st for a 56 stpd operation to $368/st for a 452 stpd operation.

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[1] Mining Engineer, Juneau Mineral Information Center, U.S. Bureau of Land Management, Juneau, AK.

INTRODUCTION

This report is one of a series produced in conjunction with the Bureau of Land Management's (BLM) ongoing mineral assessment program and is authorized under the Alaska National Interest Lands Conservation Act (ANILCA, Section 1010). These studies assist the BLM in its long term objectives for management of federal lands and minerals assets. Objectives include making available necessary mineral resources to meet national, regional and local needs, considering mineral and non-mineral resource values in decision making, assuring that mineral resource exploration, development, extraction, and reclamation operations are optimized, and environmental and other resource disturbances are minimized, and assuring a fair value return to the government from the development of its mineral resources.

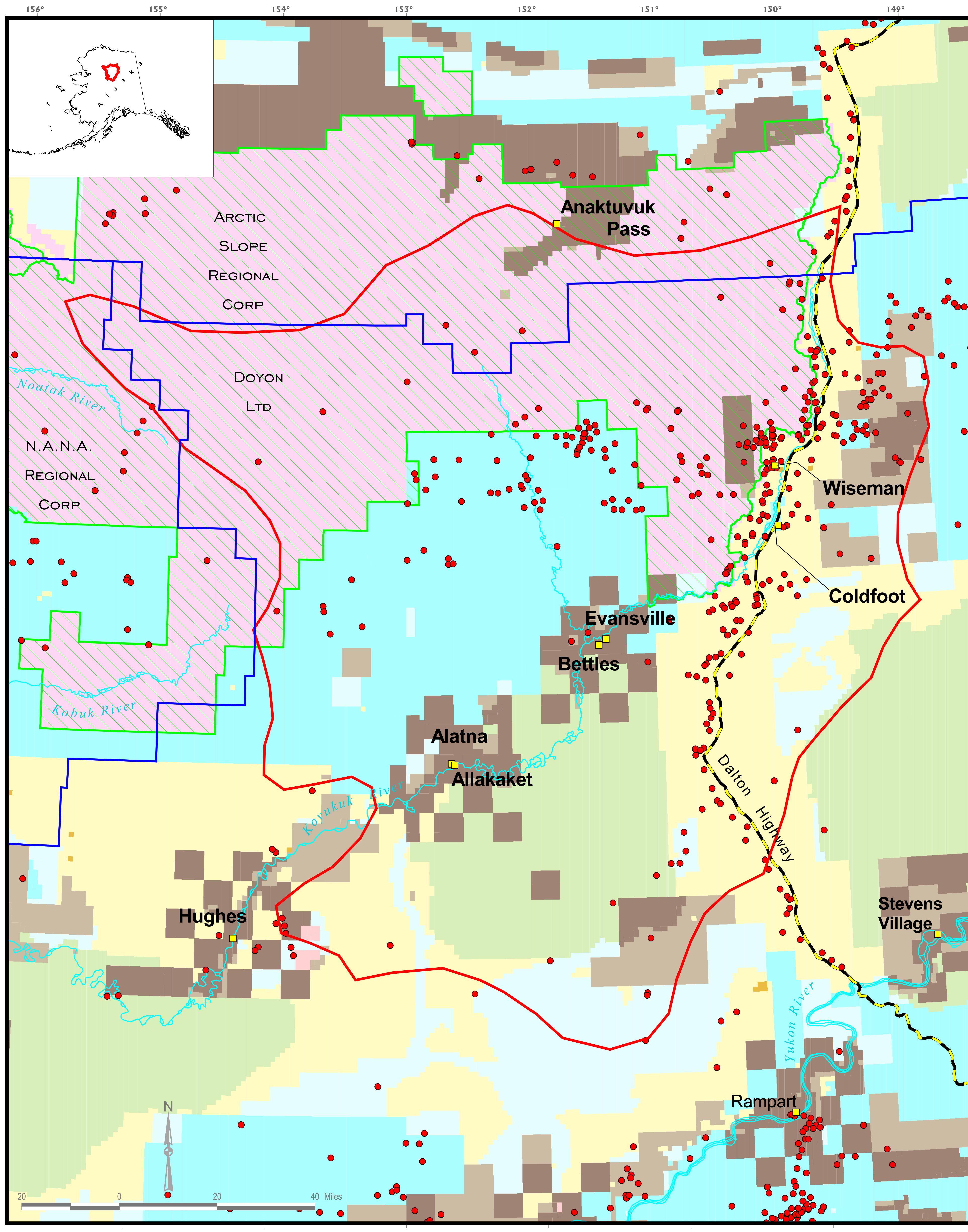
Mineral assessments include surveying, mapping, and sampling of historic mines, prospects, and mineral occurrences as well as reconnaissance investigations of prospective mineralized areas. The objective is to determine the type, amount, and distribution of mineral deposits which are used in evaluating the area's mineral development potential.

Economic prefeasibility studies were conducted on typical mineral deposit types found in the Koyukuk Mining District (Figure 1). Two factors were addressed in this study: the magnitude of the resource that would have to exist, and the recoverable metal value (RMV) that would be necessary to make a deposit economically feasible to mine. The RMV is the combined dollar value of all saleable products from a given mineral deposit expressed in dollars per short ton ($/st) or dollars per loose cubic yard ($/lcy) and is equal to the amount of revenues required before all expenses including royalties, mining and milling capital and operating costs, off-site transportation costs, smelting charges, and taxes are deducted. The interrelation between these factors is shown in tabular and graphical form.

In order to make these economic assessments for the gold placer, copper porphyry, copper skarn, mineralized quartz veins, and massive sulfide deposits existing mineral deposit information was used whenever possible. Mineral deposit grades and supporting background information were furnished by the BLM's mineral assessment personnel. Additional information was retrieved from the Minerals Availability System (MAS) database.

Detailed deposit characteristics such as depth, thickness, orientation, and volume have not been determined for the partially explored deposits used as examples in this study, so assumptions were made. These assumptions are discussed at the beginning of each deposit characteristics section. A spatial analysis was conducted to estimate road building requirements for potential gold placer mines located in the district.

Nine groups of models are included in the report. For the reader's convenience, each group includes an individual stand-alone description of the hypothetical mine and mill models applied to each deposit type. Although repetitious, this style of presentation was selected for the sake of clarity and for ease of use. For the benefit of readers interested in only one of the models, an individual description which includes a tabular and graphical summary of cash flow analysis, and the accompanying material from the appendices could be copied for separate use from the report.



Projection: UTM, NAD27, zone 5
Date / source of data:
Land Status - 12/20/2000 (BLM)
MILS - various (historical) (USBM / BLM)
ANCSA - 1987 (BLM)
Date of map: 7/2001

The information depicted on this map should be used for graphic display only. For official land status, refer to Cadastral Survey Plats, Master Title Plats, and case files. No warranty is made by BLM as to the accuracy, reliability, or completeness of these data for individual use or aggregate use with other data.

ANCSA (Alaska Native Claims Settlement Act)
Mining District Boundary
Towns
Major roads
Gates of the Arctic Park
Major Rivers
MILS (Mineral Industry Location System)

Land Status

Bureau of Land Management
Fish and Wildlife Service
Forest Service
Metlakatla Indian Res.
Military
National Park Service
Native Patent or IC
Native Selected
Private
State Patent or TA
State Selected

Figure 1. - General location map for the Koyukuk Mining District.

Results of field work and analytical results from the 1997-98 investigations of the Koyukuk Mining District were published as an open-file report (Kurtak, et. al., 1999). A master's thesis by a BLM volunteer geologist about the geology and gold mineralization of the Nolan Area was also published as an open-file report (Eden, 2000). The final report; in progress, will provide a comprehensive summary of results (Kurtak, et. al., in progress).

Acknowledgments

The author expresses his appreciation to Joe Kurtak, geologist, Anchorage Solid Minerals Section for making possible the field trip to the Koyukuk Mining District in summer 1999 and the chance to observe several of the gold placer mining operations firsthand. Special thanks to John Clark, geologist, Student Temporary Employment Program (STEP), graduate student, University of Alaska Fairbanks, for organizing and conducting the tour of mines during my field trip. Thanks to Silverado Gold Mines Inc. for their hospitality and accommodations at the Nolan Creek Mine Camp.

Location and Access

The following descriptions of location, access, and land status were modified from Kurtak and others (Kurtak, et. al, 1999). The Koyukuk Mining District, (11.6 million acres) located in the northern interior of Alaska, is bounded on the north by the crest of the Brook Range, the west by the Noatak and Kobuk rivers, and the east by the Chandalar River. The southern boundary is the confluence of the Kanuti and Koyukuk rivers.

The Dalton Highway provides year round access to the eastern part of the district. Trails branching off the Dalton Highway provide ground access to some mine sites during winter. Lowland areas consist primarily of small lakes, marshes, and muskeg, making overland travel during summer months difficult. The most practical method of access is by helicopter or small fixed-wing aircraft. Use of shallow drift boats is possible on the larger rivers in the district, such as the South Fork Koyukuk River in summer, but there is no commercial barge service due to shallow water.

The Indian and Ray mountains, with summits rising to 4,800 feet, are located along the southern boundary of the district. Small local glaciers originate from the higher parts of the Indian Mountains. To the north, the Kanuti Flats, which comprise the majority of the southern portion of the district, are unglaciated low plains, with numerous lakes and little to no rock exposure. The lower elevations are vegetated with black and white spruce, poplar, birch, alder, and willow with low sedge tussock-covered hills.

The Endicott Mountains, which make up the Central Brooks Range, are located in the northern half of the district. Vegetation similar to the Kanuti Flats is dominant in lower elevations. Tundra covering is abundant in the higher elevations, with timberline ranging between 2,000 and 3,000 feet. River valleys and high mountain peaks with cirque glaciers make up the topography of the mountains. The area north of the trunk of the Koyukuk River lies within the continuous permafrost zone. Three-quarters of the district is located above the Arctic Circle.

The district's climate is dominated by the continental climate zone of Alaska. This climate zone is characterized by warm summers and extremely cold winters. The average total precipitation for the district is 13.6 inches with an average snowfall total of 85.4 inches. The extremes are 93^{o} F and -82^{o} F, an unofficial North American low temperature record at Coldfoot in 1989.

Allakaket has no road link, but winter trails connect it with Hughes, Bettles, and Tanana. State-owned lighted runways are accessible in Allakaket, Bettles, and Coldfoot. A restricted-use runway exists at the Indian Mtn. Radar site.

During four months of the year, the Hickel Trail, a 30-mile winter road connects Bettles and Evansville to the Dalton Highway. The State-owned airport is classified as a transport center, with a flight service station and a float pond. Trucks, cars, snow machines, and all-terrain-vehicles (ATV) are used for local transportation. During the summer months access is by aircraft only.

The North Slope Borough maintains an airstrip, year-round at Anaktuvuk Pass. There is no road to Anaktuvuk Pass, but "Cat-trains" transport cargo from the Dalton Highway during the winter months. Snow machines and ATVs are used for local transportation.

Land Status

The district is comprised of federal, state, and native corporation lands. Federal lands make up 72% of the district, including Gates of the Arctic National Park (GANP) and the Kanuti Wildlife Refuge; these lands are closed to mineral entry. Twenty-one percent of the district is controlled by the State of Alaska with the remaining 7% held by Native corporations, Doyon Corporation being the largest landowner.

Environmental and Socioeconomic Issues

Few permanent settlements are located within the district, and these have relatively small populations. According to December 1999 population estimates by the Alaska Department of Community and Economic Development, the population of the upper Koyukuk is about 650 people distributed as follows: Alatna - 34, Allakaket - 204, Anaktuvuk Pass - 314, Bettles - 35, Evansville - 24, Coldfoot - 20, Wiseman - 20.

This study does not address environmental and socioeconomic concerns. For each model the acquisition cost represents the cost of mine permitting activities, environmental studies such as baseline data collection, water quality sampling and monitoring, wildlife studies, preparation of permit applications to the required local, state, and federal agencies, and other related activities.

Environmental issues that may arise during the course of mineral development may include, but are not limited to access, aquatic ecosystem integrity, economic impacts, fish habitat, fisheries, heavy metals contamination, hydrologic changes, impact to scenic values, impacts from past mining operations, impacts on subsistence, impacts on visitor use, impacts from access, long-term and short-term impacts, monitoring and enforcement, reclamation, threatened and endangered species, water quality, wetlands impacts, wilderness, and wildlife habitat.

Socioeconomic concerns may include but are not limited to potential impacts on the population (population increase, movement, or relocation in response to the project), public services and facilities, housing supply, employment, education (e.g. student population increase), local, state and federal tax revenues and expenditures, transportation, and quality of life (Berger, 1991).

Mitigation measures and associated costs developed during the permitting process are unique for each mineral development project. It is difficult to estimate these costs without benefit of public scoping and at least a preliminary environmental and socioeconomic assessment for the proposed mineral development project. These issues and the associated costs of mitigation are beyond the scope of this preliminary study, and are not addressed in the economic models.

Field Observations

The only type of mining done during summer 1999 in the Koyukuk Mining District was placer mining. There were no copper porphyry, copper skarn, mineralized quartz vein, or massive sulfide mining operations observed in the district. Hypothetical mine models for these deposit types are included in this report.

The decline in gold prices in recent years has had a significant impact on the operations in the district. Average gold prices of about $389 per troy ounce (tr oz) in 1996 fell to about $280/tr oz in 1999 and remained unchanged during 2000 (U.S. Geological Survey, 2000, 2001). Premium prices of 60% or more above average prices may be obtained for jewelry quality gold nuggets, but this has not been enough to offset the impacts of lower gold prices. Many operations were idle during the summer of 1999 when the author made a field trip to the district. In some cases, only assessment work was being done and there was no production. Mine sites visited included Nolan Creek, Lofty Gulch, Linda Creek, Porcupine Creek and Birch Creek.

With the exception of Silverado Gold Mines Inc.'s Nolan Gold Project , most operations are small scale. In 1994, Silverado Gold Mines Inc. was the largest placer gold producer in the Koyukuk Mining District, recovering 8,024 tr oz from their large surface and underground operation on Nolan Creek (Kurtak, et al, 1999). The Nolan Gold Project was idle with three employees to maintain the camp in the summer of 1999. No mining was done during the summer of 1999, but gravels removed from an underground drift mine the previous winter were washed.

There were nine permitted/active gold placer operations in 1999. Two operations were literally a one person operation, and one other surface operation at Rye Creek had six persons. One underground operation at Linda Creek with four persons was also observed.

Typically, these small ventures do not have any employees. The workers may be owners, partners, or shareholders contributing their efforts for a share of the production. This organizational structure and risk sharing makes it possible for these ventures to continue during periods of low gold prices.

Economies of scale would normally suggest that the much larger Nolan Gold Project should have been operating in the summer of 1999 rather than these smaller operations. The difference is that the Nolan Gold Project was forced to lay off it's employees, whereas the smaller operations continued operating because these smaller operation's labor force consisted of it's owners, partners, or shareholders. As such, labor was not an operating cost that had to be paid, but a cost that would be paid only if a profit was made.

The mining season varies considerably, some operators produced for only 30 days, others selected longer seasons. Operating season variation was due to low gold prices causing short operating seasons or, in some cases, shutdowns. The Nolan Gold Project at one time operated nearly year round in the mid 1990's with underground mining in the winter months and surface mining and processing during the summer months.

One placer mine was operated as a tourist-oriented business. The owner organized tours and rented mining equipment and cabins to groups of tourists that enjoyed recreational gold panning, hiking, and the outdoor experience.

One placer mine was operated as a fly-in camp. The partners operated the mine during the summer months, and the camp was supported with air cargo flights from Coldfoot and Fairbanks. Work time at the camp was proportionately scheduled to each individual's interest in the partnership. The partners returned to their regular employment during the non-summer months.

Operations were suited to site specific criteria. Equipment choices varied and seemed in part to depend on the availability of used equipment in the immediate area. Front end loaders at Rye Creek, backhoes at Hammond River, bulldozers at Union Gulch, and load-haul-dumps (LHD) at Linda Creek were representative of the equipment employed in these operations. Survey results of a BLM questionnaire circulated to the district's placer miners were inconclusive, and developing a profile of a typical placer gold mining operation was not possible.

Transportation Requirements of the Koyukuk Mining District

Through the use of geographic information system (GIS) software, the Koyukuk Mining District was divided into 9 analysis areas to estimate road building requirements for potential gold placer mines. Figure 2 depicts the analysis areas. As the district is approximately 11.6 million acres in size, road building requirements can vary considerably. Many of the placer mines are favorably located in close proximity to the Dalton Highway.

Transportation needs of mines in the district can vary considerably and will change during the course of exploration, development, and production. Operators aren't restricted to just one choice. During the exploration stage, infrastructure investments are generally minimized to the extent possible due to the uncertain nature of exploration success. A fly-in camp with air support from helicopters or planes is often the preferred choice at this stage. During the development and production stages, roads (unsurfaced or gravel-surfaced), winter trail, or air access may be used, depending on the site-specific characteristics of the mine. Gold Dust Mines Inc.'s Chandalar Lake operation located about 20 mi east of the Koyukuk Mining District's eastern boundary uses all three; an 80 mi winter trail for access from the Dalton Highway, 15 mi of roads at the mine site to connect four separate claim blocks, and an airstrip.

Mobilization may require more than one method of transportation. For example, with no existing airstrip, construction materials needed to build an airstrip might be sledded in during the winter months or possibly slung in with a helicopter. Air support can reduce costly downtime, providing the items being transported don't exceed the cargo plane's internal fuselage dimensions. Larger items may be partially disassembled, transported, and then reassembled on site. Transporting fuel is subject to permitting or legal requirements.

The center of the nine individual analysis areas were selected as the destination of a hypothetical road that would be built from the Dalton Highway. Air distances to the center of these nine analysis areas from Fairbanks were also measured. Based on the analysis, hypothetical surface and underground placer mines were modeled with requirements for a 10 mi, 50 mi, and 100 mi pioneer road, and compared to a hypothetical air-supported operation located about 200 miles from Fairbanks.

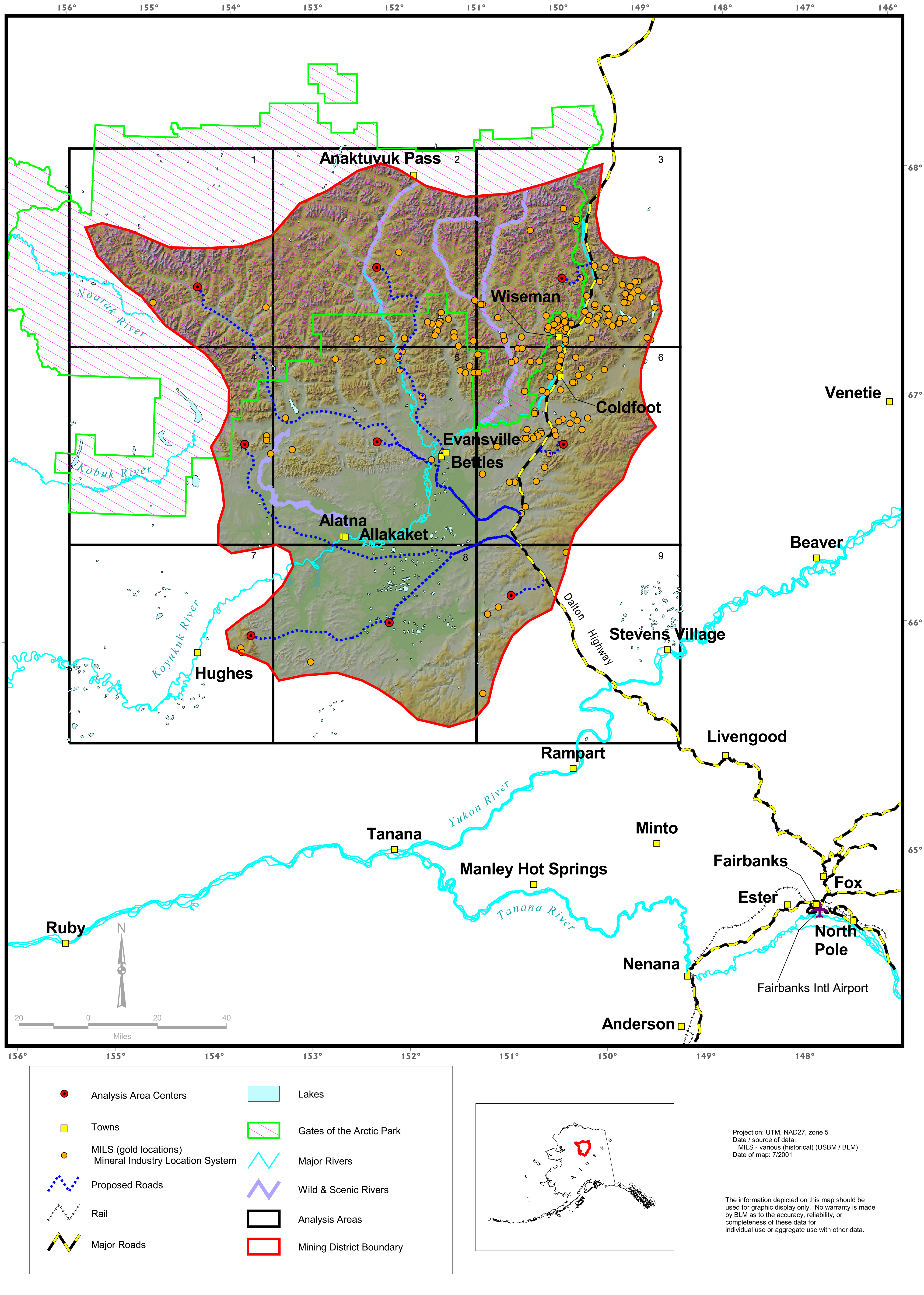


Figure 2. - Analysis Areas for the Koyukuk Mining District.

Surface and underground placer mine models based on the use of winter trails of various lengths (10 mi, 50 mi, 100 mi) were developed and compared to an air-supported operation (assumed to be located about 200 mi from Fairbanks). The winter trail would connect the hypothetical operation to the Dalton Highway, the Tanana Allakaket Winter Trail, or the Hickel Trail.

Costs for winter trails are highly variable depending on terrain obstacles, bridging requirements for steep grades, deep gullies, the number of stream crossings, and/or the amount of clearing necessary in forested areas. Maintenance costs vary with the amount of traffic, snowfall, and other factors. Costs for winter trail construction and maintenance were estimated based on information from Gold Dust Mines, Inc. (Del Ackels, Gold Dust Mines, Inc., written commun., 2001).

Table 1. - Transportation requirements of the Koyukuk Mining District

Analysis area	Hypothetical road length (miles)	Air distance from Fairbanks (miles)
1	133	267
2	110	237
3	14	207
4	101	224
5	54	195
6	11	160
7	90	191
8	47	156
9	12	132

ECONOMIC MINE PREFEASIBILITY STUDIES

Economic prefeasibility studies for five mineral deposits types were conducted to establish the RMV per short ton (st) or loose cubic yard (lcy) necessary to meet a 15% discounted-cash-flow rate-of-return (DCFROR). The definition of RMV as given by Baggs and Sherman in previous U.S. Bureau of Mines (USBM) economic studies was used (Baggs, et. al 1987, Sherman, et. al 1988).

The RMV is the combined dollar value of all saleable products from a given mineral deposit expressed in \$/st or \$/lcy. The RMV was used to reduce the individual effects of commodity grades, recoveries, and metal prices to a common base, so that a single curve relating ore value of the deposit to DCFROR could be created.

This report considers several factors controlling the feasibility of mineral development, including physical attributes and geographic location of the deposit, metallurgical attributes of the minerals, metal markets, and infrastructure availability. Additional factors such as perceived risk, political and economic climate, environmental constraints, and corporate policy may be present but aren’t considered.

Capital and operating costs for the surface placer gold models were determined using the USBM's Cost Estimation Handbook for Small Placer Mines (Stebbins, 1987). Capital and operating costs for the underground placer gold models were determined using the Underground Mining of Frozen Placers (Bandopadhyay and others, 1993).

Gold Dust Mines Inc. provided cost information on pioneer roads, winter trails, and material requirements based on the company's extensive experience with winter trails on the leased claims that it operates near Chandalar Lake (Del Ackels, Gold Dust Mines, Inc., written commun., 2001).

These models were supplemented with additional information from Simplified Cost Models for Prefeasibility Mineral Evaluations (Camm, 1991) and PREVAL: Prefeasibility Software Program For Evaluating Mineral Properties (Smith, 1992). Capital and operating costs for the porphyry copper models were determined using the USBM Cost Estimation System (CES) version 2.3 (U.S. Bureau of Mines, 1995). Capital and operating costs for the copper skarn, massive sulfide, and mineralized quartz vein models were determined using the Mining Cost Service (Schumacher, 2000) and supplemented with computer modeling based on the SHERPA Automated Mine Cost Engineering System[2].

Cost estimates were escalated using the USBM's Alaska Mineral Industry Cost Escalation Factors (AMICEF) of 1.49 for operating labor, 1.58 for capital labor, 1.15 for capital costs, and 1.60 for electricity to reflect higher costs in the Koyukuk Mining District. These factors are a set of calculated values used to escalate itemized capital and operating costs for mining and milling operations in the central front range of the Rocky Mountains (Denver vicinity) to any point in Alaska. The Denver vicinity is used as the base for CES (Balen and Allen, 1993)

Published cost information from permitting documents, environmental impact statements, and private reports were also used (U.S.D.A. Forest Service, 1983, 1991, U.S. Environmental Protection Agency, et. al, 1984). All cost estimates are expressed in 2000 dollars.

Using the estimated capital and operating costs, economic models were compiled using cash flow analysis techniques. The RMV and DCFROR were computed. See Appendix A for the capital and operating costs of the economic models and Appendix B for the economic assumptions, sample calculation of RMV, and the inflation-adjusted 10, 20, and 30 year commodity price averages.

Surface gold placer mine models

Gold placer deposit models are described as elemental gold and platinum-group alloys in grains and nuggets in gravel, sand, silt, and clay, and their consolidated equivalents, in alluvial, beach, eolian, and glacial deposits. The highest gold values are usually at the base of gravel deposits in various gold "traps" such as natural riffles in the floor of rivers or streams, fractured bedrock, slate, schist, phyllite, dikes, bedding planes, all structures trending transverse to direction of water flow. Gold concentrations also occur within gravel deposits above clay layers that constrain the downward migration of gold particles (Cox and Singer, 1987).

[2] Mention of SHERPA Automated Mine Cost Engineering System does not signify BLM endorsement.

There are three general categories of placer deposits in the district: 1) placers that lie at or just below the level of the modern stream or river channel. These deposits, though often lower grade, are the most economic to mine due to shallow overburden. Gold is concentrated on bedrock or in the lower part of gravels that range from a few inches to 10 ft thick. These deposits have been mined out in the district. 2) Deep channel placers concentrated on bedrock in deeply cut paleo stream channels now covered by up to 200 ft of gravel and overburden. These placers tend to be the richest in the district, but the cost of mining is exceptionally high as underground methods are required 3) Bench placers deposited in paleo channels cut by streams from 2 to 360 ft above the modern channels. Some stream valley placers are on benches cut at multiple levels (Kurtak and others, 1999).

State of Alaska Annual Placer Mining Applications (APMA) were examined to determine operating seasons for typical placer mining operations. Twenty six operations reported seasons ranging from 90 days to year-round. An underground operation at Linda Creek was the only placer operation reporting a year-round season.

The average operating season for the 26 operations was 179 days. Average sluicing days was 76, ranging from 15 to120. On average, sluicing days were about 44% of total season days. Twelve operations reported a May 1 starting date, with 10 operations reporting a season end date of September 30 or October 1.

Longer seasons may not necessarily be more productive, especially in the case of surface placer gold mine. Productivity falls sharply as the weather becomes more inclement. Mining and processing operations become increasingly difficult, eventually reaching the point when the operation has to be closed for the winter. Some operators select shorter seasons for this reason. Underground mining can continue during the winter, but sluicing operations must be postponed until spring time.

Impediments to the operating season can be other events, such as flooding, which may disrupt settling ponds and mining operations, or on the opposite side, lack of precipitation, which may create water shortages and have adverse effects on processing. Unseasonable weather, such as the early arrival of winter curtailing operations, or a prolonged winter delaying the start of a new operating season may occur sometimes.

There was considerable variation in the 26 operations. The number of workers ranged from 2 to 15 persons, with gravel processing ranging from 1,500 to 580,000 cubic yards annually. It should be noted that this data is based on proposed mining plans rather than actual operations. Submission of an APMA does not necessarily mean the mine actually operated during the season.

The gold placer models included in this report are based on hypothetical placer operations processing 43,700 to 349,400 cubic yards with 4 to 10 persons in a 180 day operating season. The hypothetical models described in this report can be used for order-of-magnitude estimates based on limited deposit information. The models are entirely hypothetical and do not accurately represent any existing mining operation in the Koyukuk Mining District.

Costs are dependent on numerous site-specific factors at each individual gold placer mining property. These factors may include, but are not limited to geologic characteristics (amount, grade and size, shape, stripping ratio, configuration of the pay gravel and overburden), mining equipment selected (front end loaders, backhoes, bulldozers, LHDs), road, winter trail, airstrip requirements, electrical power generation and other infrastructure requirements, type of processing selection (sluices, shaker/screens, jigs, trommels, etc.), number of stream diversions, number of settling ponds, reclamation requirements, etc.

Thirty-five mine models were developed. The models assume that a bulldozer will be used to mine the deposit and a feeder hopper, conveyor belt, and sluice box arrangement will be used for processing. This arrangement is selected because it requires a lower initial capital investment. The same hypothetical model was used and adjusted for various access assumptions.

Seven groups of five mines were modeled to simulate various transportation alternatives as follows: road support (10 mi, 50 mi, 100 mi) to connect to the existing road system, winter trail support (10 mi, 50 mi, 100 mi) to connect to the existing road system or another winter trail, and air supported access (200 mi air distance).

Each of the seven groups of mines were modeled with five resource sizes ranging from 148,880 to 2,302,080 bank cubic yards (bcy) (179,850 - 2,877,600 lcy). For purposes of this report, an average swell factor of gravel of 25% was used (Wells, 1969). A typical mining cycle for the 243 loose cubic yards per day (lcy/d) model would include removing about 73 lcy/d of overburden, mining about 243 lcy/d of pay gravel, processing with a sluice box, then moving the tailings to the approximate location they will occupy at final reclamation.

Actual amounts of overburden encountered at mining operations in the district will vary, and may be less than or greater than amounts assumed in this report. Larger size models use the same ratio of overburden to pay gravel. Process water would be recycled as necessary to meet discharge permit requirements and also to support mining operations during periods of low precipitation as necessary.

Small mines generally operate with used equipment instead of new equipment. The capital cost of used equipment may range from approximately 25 to 50% less than comparable new equipment, however this savings to the operator is offset by increased operating costs accrued by equipment having over 10,000 hours of previous service life. Increased down-time is common.

A down-time factor of about 30% is assumed. Selected equipment was oversized to compensate for down-time in order that the equipment could still move the desired amounts of pay gravel, tailings, and overburden in the time available. The individual experience of placer mine operators may show considerable variation in results based on the quality of the used equipment they acquired for their operation (Stebbins, 1987)

The bulldozer represents an extremely versatile tool and can be used for overburden removal, pay gravel extraction, bedrock cleanup, overburden and pay gravel transportation, road construction, tailings placement, and a variety of minor functions. The bulldozer is the only device capable of handling all tasks required for placer mining in a practical manner, although it may not necessarily be the most efficient machine for any one task (Stebbins, 1987).

Sluice boxes are the most common gravity separation device used in the industry; simple to construct, yet effective heavy mineral recovery tools. Sluice design is quite diverse, and opinions differ widely with respect to capacity, riffle design, and recovery. In general, capacities and performances vary with box-width and slope, gold particle size, nature of feed, and availability of water (Stebbins, 1987).

It is assumed that used travel trailers or used Atco-type buildings would be used for housing and sized according to personnel needs. These trailers are sometimes referred to as recreational or camping trailers and are about 8 feet wide and range in length from 19 to 37 feet. As most small placer mines are operated on a limited budget, travel trailers are a popular choice among the district's placer miners for meeting housing needs in these seasonal operations. It is assumed the trailers are equipped with kitchen, liquefied-petroleum-gas (LPG), fresh water tanks, bathroom, shower, gray water, and black water holding tanks appropriately sized to accommodate four to ten persons during a 180 day season. The models have relatively short mine lives of 4 to 8 years. It is assumed used trailers would be purchased.

Larger conventional house trailers were observed at Silverado Gold Mines Ltd.'s Nolan Creek operation, which was accessible by road. Mobilizing smaller travel trailers to remote sites without road access is costly, therefore, trailer sizes were minimized in the air supported models. It may be possible to skid these trailers onto the site using winter trails.

It is assumed that mines near the road system would construct a pioneer style road with no gravel, chip seal, or asphalt surfacing. If soil conditions were favorable, this type of road could be used, as it is significantly less expensive than surfaced roads. The camp would be supplied via conventional highway tractor-trailers. There are various size trailers for these types of vehicles. It is assumed that trailers with a payload of 32 st (1,308 cubic feet) would be used initially. Switching to larger or smaller trailers might be necessary after assessing this initial choice, road maintenance expenses, wear and tear on the trucks operating on this unimproved road, lower haulage speeds, and other factors.

Winter trails appear to be the lowest cost option. However, it is important to recognize that winter trails can provide only a seasonal link, and other transportation methods will be needed in the months that the winter trails are unavailable. Road building is costly and appears feasible only for mines located in close proximity to the Dalton Highway. Only the larger size mine models (i.e. 1,941 lcy/d) appear able to support access roads of any substantial length (about 35 mi). For smaller deposits where the resources are limited, mine lives are short, amortizing a road would be difficult. Air support is also costly, but may be the only option available for mines off the road system, either as a supplement during the months when winter trails aren't available or for mines that may select air support as their primary method of access. As previously noted, some operations may select a combination of pioneer roads, winter trails, or air access. Optimizing transportation costs depends on the site-specific characteristics at each individual site.

Material requirements for the 180 day operating season were estimated to range from 39 st for the smallest model to about 146 st for the largest model. Diesel fuel for equipment and electrical generators is the largest item, followed by food, equipment lubricants, parts, and other supplies.

Table 2 summarizes the cash flow analysis of the 15 surface placer mine models, using pioneer roads compared to air access. The RMV per lcy required to achieve a 15% DCFROR ranges from \$4.23/lcy for a 1,941 lcy/d placer mine supported by a 10 mi road to \$35.05/lcy for a 243 lcy/d placer mine supported by a 100 mi road. Figure 3 graphically presents the results for the surface gold placer mine models. Tables A-3 to A-6 in Appendix A summarize the capital and operating costs of the 20 surface gold placer mine models.

Table 2. - Summary of cash flow analysis for surface gold placer mine models pioneer road

Deposit size (lcy)	Mining rate (lcy/d)	RMV - 15% DCFROR ($/lcy)			
		10 mi road	50 mi road	100 mi road	200 mi air access
179,850	243	$18.11	$25.49	$35.05	$18.35
359,700	408	12.14	16.19	21.12	12.54
719,400	686	8.32	10.56	13.28	8.66
1,438,800	1,154	6.02	7.19	8.62	5.84
2,877,600	1,941	$4.23	$4.84	$5.63	$4.62

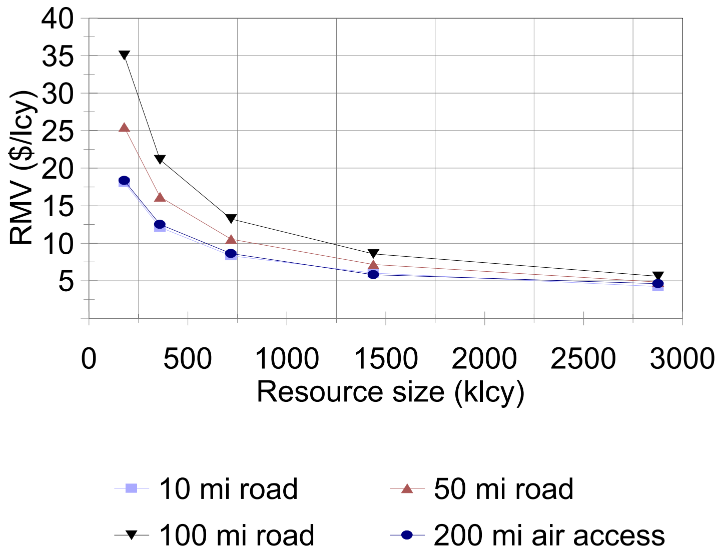


Figure 3. - RMV vs. resource size, surface gold placer mine models - pioneer road

Table 3 summarizes the cash flow analysis of the 15 surface placer mine models, using winter trails compared to air access. The RMV per lcy required to achieve a 15% DCFROR ranges from $4.11/lcy for a 1,941 lcy/d placer mine supported by a 10 mi winter trail to $18.55/lcy for a 243 lcy/d mine supported by a 100 mi winter trail. Figure 4 graphically presents the results for the surface mine models. Tables A-6 to A-9 in Appendix A summarize the capital and operating costs of the 20 mine models.

Table 3. - Summary of cash flow analysis for surface gold placer mine models winter trail

Deposit size (lcy)	Mining rate (lcy/d)	RMV - 15% DCFROR ($/lcy)			
		10 mi winter trail	50 mi winter trail	100 mi winter trail	200 mi air access
179,850	243	$16.82	$17.61	$18.55	$18.35
359,700	408	11.44	11.88	12.52	12.54
719,400	686	7.89	8.20	8.51	8.66
1,438,800	1,154	5.79	5.95	6.14	5.84
2,877,600	1,941	$4.11	$4.18	$4.30	$4.62

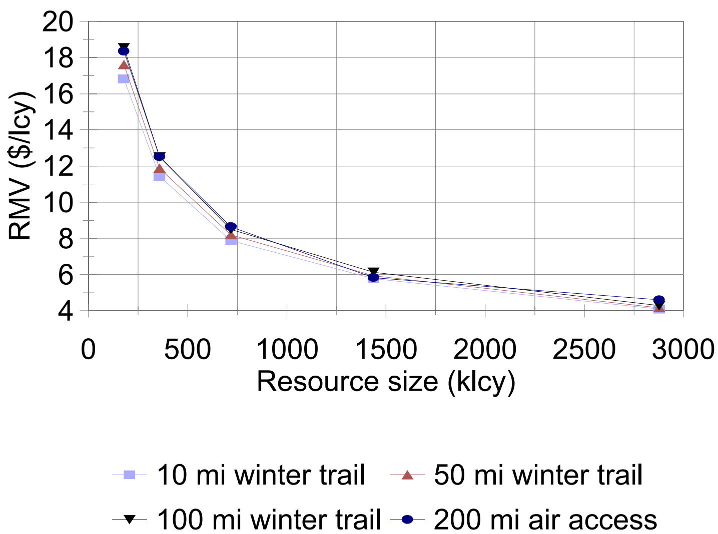


Figure 4. - RMV vs. resource size, surface gold placer mine models - winter trail

Underground gold placer mine models

The deposit is assumed to have up to several hundred feet of overburden consisting of frozen sand, silt, and gravel. It is assumed that ground support in the frozen gravels will be good, and that no extraordinary ground control measures will be required. No thawed or partially thawed gravels which may cause serious ground control problems will be encountered. These conditions have been reported in the district, but it is assumed these conditions will not be present.

Thirty five underground gold placer mine models were developed. The models assume that room and pillar mining methods would be used and it is assumed that the ore body will be horizontal or have a flat dip. The model assumes the use of jacklegs and stopers for production and stope development. The models assume that a LHD will be used to mine the deposit. A sluice box located on the surface will be used for processing the gravels after a suitable thawing time makes this possible. Mining recovery is estimated at 85% for the operation and it is assumed that the pillars would be recovered in the later part of the mine's life. The models assume a seasonal operation of 180 days per year.

Underground mines may operate on a seasonal basis in the summer or winter months, and possibly year-round if care is taken. The major concerns would be thawing caused by warmer temperatures and diesel equipment operating underground in the summer time. Good ventilation practices may help to alleviate this problem. Also of concern is the stability of any underground openings and the proper layout of development and extraction openings and their support requirements. Frozen ground can be unstable to highly stable, in part depending on permafrost temperatures, total ice content, and texture (Skudrzyk, 1990).

Other small underground mines around the state have operated by mining in the winter months and stockpiling the pay gravels, which is then sluiced during the summer months. Examples include several small operations on Dome Creek and lower Goldstream Valley near Fox; Little Eldorado Creek in the Fairbanks Mining District; one in the Inmachuk district near Deering on the Seward Peninsula; and the Nolan Creek operation near Wiseman. The small underground drift mine on Linda Creek has operated during the summer months (Bundtzen and others, 1992, 1994; Swainbank and others,1993).

Seven groups of five underground mines were modeled to simulate various transportation alternatives as follows: road support (10 mi, 50 mi, 100 mi) to connect to the existing road system, winter trail support (10 mi, 50 mi, 100 mi) to connect to the existing road system or another winter trail, and air supported access (200 mi air distance) as a remote fly-in camp.

Underground mines were modeled on five resource sizes ranging from 148,880 to 2,302,080 bcy (179,850 to 2,877,600 lcy). Tailings will be moved by a LHD. Process water would be recycled as necessary to meet discharge permit requirements and also to support mining operations during periods of low precipitation as necessary. Conclusions about transportation costs for the underground placer models are similar to the surface placer models.

Table 4 summarizes the cash flow analysis of the 15 underground gold placer models, with pioneer roads compared with air access. The RMV per lcy required to achieve a 15% DCFROR ranges from \$6.41/lcy for a 1,941 lcy/d placer mine supported by a 10 mi road to \$36.04/lcy for a 243 lcy/d placer mine supported by a 100 mi road. Figure 5 graphically presents the results for the underground gold placer mine models. Tables A-10 to A-13 in Appendix A summarize the capital and operating costs of the 20 underground placer mine models.

Table 4. - Summary of cash flow analysis for underground (U/G) gold placer mine models pioneer road

Deposit size (lcy)	Mining rate (lcy/d)	RMV - 15% DCFROR ($/lcy)			
		10 mi road	50 mi road	100 mi road	200 mi air access
179,850	243	$19.73	$26.82	$36.04	$19.33
359,700	408	14.42	18.25	23.03	14.51
719,400	686	10.59	12.74	15.38	10.89
1,438,800	1,154	8.09	9.23	10.64	8.47
2,877,600	1,941	$6.41	$7.04	$7.82	$6.81

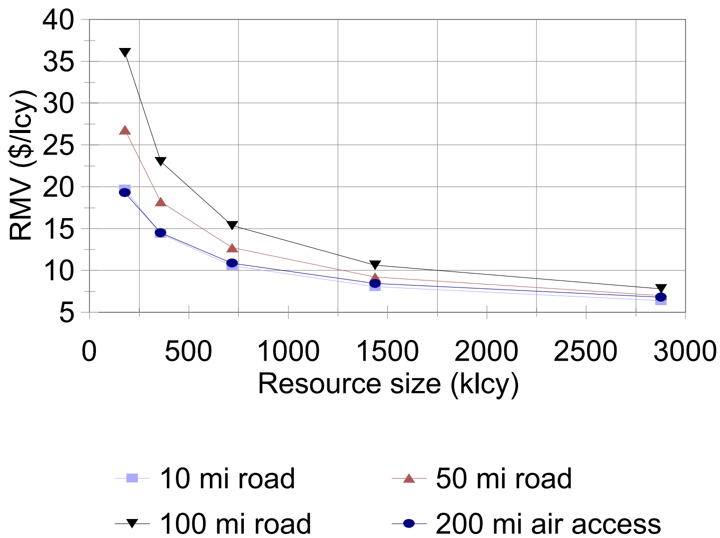


Figure 5. - RMV vs. resource size, underground gold placer mine models - pioneer road

Fifteen underground gold placer mine models were developed which utilized large crawler type tractors towing sleds for movement of personnel and supplies over winter trails. These tractor-sled combinations, known as “cat trains”, have been used extensively for heavy transport as well as petroleum exploration (Louis Berger and Associates, Inc.,et. al, 1980). Similar to the surface gold placer mine models, various models were developed with winter trail support (10 mi, 50 mi, and 100 mi) and compared to an air supported remote fly-in camp type arrangement.

Table 5 summarizes the cash flow analysis of the 15 underground gold placer mines, with winter trails compared to air access. The RMV per lcy required to achieve a 15% DCFROR ranges from $6.28/lcy for a 1,941 lcy/d placer mine supported by a 10 mi winter trail to $19.99/lcy for a 243 lcy/d placer mine supported by a 100 mi winter trail. Figure 6 graphically presents the results for the underground gold placer mine models. Tables A-13 to A-16 in Appendix A summarize the capital and operating costs of the 20 underground placer mine models.

Table 5. - Summary of cash flow analysis for underground (U/G) gold placer mine models winter trail

Deposit size (lcy)	Mining rate (lcy/d)	RMV - 15% DCFROR ($/lcy)			
		10 mi winter trial	50 mi winter trail	100 mi winter trail	200 mi air access
179,850	243	$18.19	$18.86	$19.99	$19.33
359,700	408	13.52	14.04	14.57	14.51
719,400	686	10.18	10.45	10.75	10.89
1,438,800	1,154	7.87	8.03	8.20	8.47
2,877,600	1,941	$6.28	$6.37	$6.51	$6.81

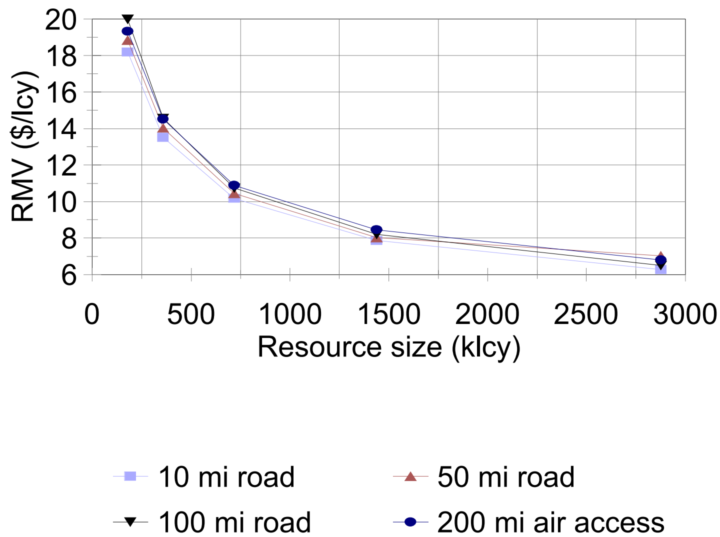


Figure 6. - RMV vs. resource size, underground gold placer models - winter trail

Surface - Underground gold placer mine models

Approximate RMVs for various combinations of surface and underground gold placer mine models are found in Tables A-24 to A-30 in Appendix A. Actual RMVs will be lower due to the savings from utilizing common infrastructure and facilities year-round. These tables approximate mine models similar to Silverado Gold Mines, Inc.'s road-accessible Nolan Gold Project, which at one time operated nearly year-round, with underground mining in the winter months, and surface mining and processing during the summer months. Year-round operation offers greater production and faster cost recovery.

Combined bulldozer/backhoe operation

The RMVs in Tables 2 to 5 can be adjusted to reflect the addition of a backhoe to the mining operation. Table 6 lists the increase in the RMV required to support the additional expense of a backhoe and a laborer. This value should be added to the appropriate RMV from Tables 2 to 5 to estimate the new RMV necessary for a combination bulldozer/backhoe operation. Figure 7 graphically presents the results for the surface gold placer mine models.

Table 6. - Additional RMV required for combination bulldozer/backhoe operation

Deposit size (lcy)	Mining rate (lcy/d)	Additional RMV ($/lcy)
179,850	243	$2.18
359,700	408	1.30
719,400	686	0.76
1,438,800	1,154	0.44
2,877,600	1,941	$0.25

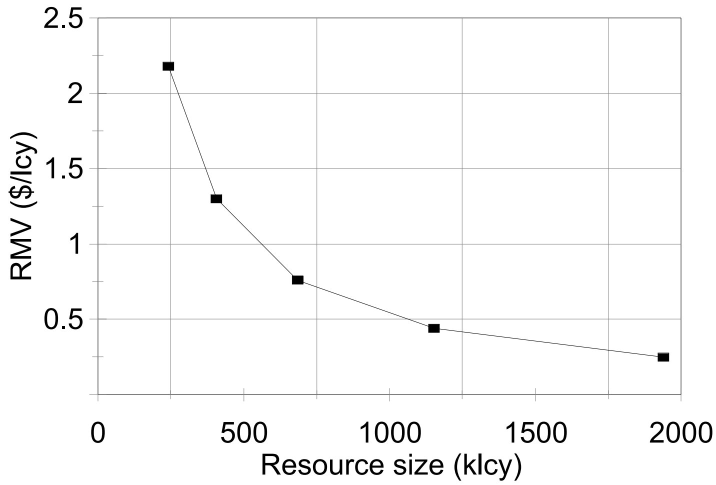


Figure 7. - Incremental RMV required for combined bulldozer/backhoe operation

Copper Porphyry Mine Models

The copper porphyry deposit model is based on the geology of a mineralized occurrence similar to the Venus prospect on Big Spruce Creek in the district (Kurtak and others, 1999, p. 20). The deposit model is described by Cox and Singer (1987) as stockwork veinlets of quartz, chalcopyrite, and molybdenite in or near a porphyritic intrusion. Metallic minerals include chalcopyrite, pyrite, and molybdenite. Peripheral vein or replacement deposits contain chalcopyrite, sphalerite, galena, and gold. Outermost zones may have veins of copper-silver-antimony-sulfides, barite, and gold.

The mine models designed for application to the copper porphyry deposit models assume that the deposit is located near surface, and the structural characteristics of the orebody are such that open pit mining methods are applicable. Resource sizes from 17 to 276 million short tons were modeled to represent the possible size for this deposit type.

Transportation to the hypothetical mine would be provided by a 22 mi road built to connect the operation to the Dalton Highway. Containerized copper concentrate shipments would be trucked approximately 311 mi to Fairbanks. The concentrates would then be transported via the Alaska Railroad approximately 470 mi from Fairbanks to Seward. Concentrates would be shipped year-round to a smelter, assumed to be located in Japan.

A new marine terminal and ship loading facility would be built to handle the hypothetical mine's containerized copper concentrates, but the facility would share some of the existing terminal's infrastructure. Seward has long been a transportation center as the southern terminus for the Alaska Railroad, with road links to Anchorage and the Interior. Seward has a coal export facility for the Usibelli Coal Mine. The port serves cruise ships, the State Ferry, cargo barges, and ocean freighters from Seattle and overseas. The Alaska Railroad provides over 1.4 billion pounds (lbs) of cargo transit each year, importing cargo for the Interior and exporting coal to the Pacific Rim.

It is assumed that the mine operator would retain the services of a commercial stevedoring firm to handle receiving, mineral concentrate storage, reclaiming, and shiploading. A trucking firm would handle both incoming supplies and fuel delivery to the mine and outgoing mineral concentrate shipments for the majority of the mine's shipping needs.

Five open pit mine models were developed for application to this deposit model. In each mine model, the associated mill uses one-product- flotation to process the ore. Open-pit mine models assume the use of rubber-tired front-end loaders, trucks, and percussion drills. The stripping ratio is assumed to be 1:1. One concentrate storage building at the mill-site capable of storing six weeks of concentrate was assumed. Containerized concentrate would be trucked to the rail load-out facility. Containerizing the concentrate prevents product loss between the mine and the final destination at the smelter and also minimizes environmental problems associated with handling sulfide minerals. Electric power would be produced using on-site diesel powered generators.

The local population in the immediate area would be insufficient for recruiting a work force. The hypothetical mining operation would provide a permanent accommodation complex for the employees. It is assumed employees would work a two-weeks-on, two-weeks-off schedule. One-third of the employees would be on their scheduled days off at anytime. Two-thirds would be on-site for their scheduled work assignments.

As the proposed mine could be accessed from the Dalton Highway, it is assumed that the work force would commute to the mine at their own expense. Initially, employees would commute from communities located in the upper Koyukuk, and also from more distant communities such as Fairbanks. In the long term, it is assumed the population and housing supply would increase in the local communities, but employees would still bear the commuting expense.

It is assumed that a suitable tailings pond could be located within a half-mile of the mill. Land area requirements were estimated as follows: for a 5-year mine life - 17 acres per 1,000 short tons per day (stpd) mill capacity, for a 10-year mine life - 32 acres per 1,000 stpd mill capacity, and for a 20-year mine life - 62 acres per 1,000 stpd capacity (Ritcey, 1989).

Table 7 summarizes the cash flow analysis of the copper porphyry mine models. The RMV per st required to achieve a 15% DCFROR ranges from $37/st for a 31,309 stpd mine to $90/st for a 3,913 stpd operation. Figure 8 graphically presents the results for the copper porphyry mine models. Table A-17 in Appendix A summarizes the capital and operating costs of the five copper porphyry mine models.

Table 7. - Summary of cash flow analysis for copper porphyry mine models

Deposit size (Mst)	Mining rate (stpd)	RMV - 15% DCFROR ($/st)
17	3,913	$90
34	6,582	74
68	11,069	53
138	18,616	46
276	31,309	$37

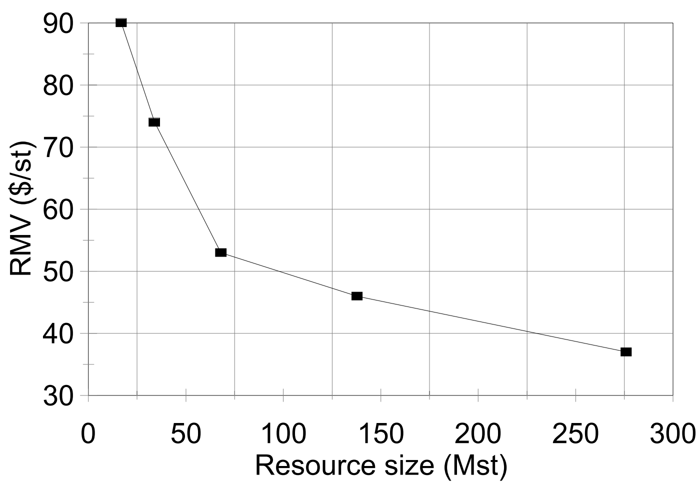


Figure 8. - RMV vs. resource size, copper porphyry mine models

Copper Skarn Underground Mine Models

This deposit model is described by Cox and Singer (1987) as chalcopyrite in calc-silicate, contact metasomatic rocks. Metallic minerals consist of chalcopyrite, pyrite, hematite, magnetite, bornite, and pyrrhotite. Molybdenite, bismuthinite, sphalerite, galena, cosalite, arsenopyrite, enargite, tennantite, loellingite, cobaltite, and tetrahedrite may also be present. Gold and silver may be important products. Ore bodies are irregular or tabular shaped in carbonate rocks and calcareous rocks near igneous contacts or in xenoliths in igneous stocks. Associated igneous rocks are barren.

The mine models designed for the deposit model assume that the structural characteristics of the orebody are such that room and pillar mining methods are applicable. Mineable resource sizes from 154,000 to 2,470,000 st were modeled to represent the possible size for this deposit type.

Transportation to the hypothetical mine would be provided by a 22 mi road built to serve the mine and mill and join the operation to the Dalton Highway and also the Alaska Railroad. A concentrate load-out facility would be built to handle containerized copper concentrate shipments to Seward, Alaska. The approximate rail haulage distance would be about 470 mi one way.

A new marine terminal and ship loading facility would be built to handle the hypothetical mine's containerized copper concentrates. The facility would share some of the existing terminal's infrastructure currently utilized by the Seward coal terminal, which handles coal from the Usibelli coal mine operation near Healy, Alaska. Alaska Railroad lease payments would be made by the hypothetical mining firm that would develop the deposit. Terminal capacity is not anticipated to be a problem. Concentrate production from the largest copper skarn mine model is less than one-third of the current coal tonnages handled by the facility.

It is assumed that the mine operator would retain the services of a commercial stevedoring firm to handle receiving, mineral concentrate storage, reclaiming, and shiploading. A trucking firm would handle both incoming supplies and fuel delivery to the mine and outgoing mineral concentrate shipments for the majority of the mine's shipping needs. Concentrates would be shipped year-round to a smelter, assumed to be located in Japan.

Five underground room and pillar mine models were developed for application to this deposit model. In each mine model, the associated mill uses one-product-flotation to process the ore. One concentrate storage building at the mill-site capable of storing six weeks of concentrate is assumed. Containerized concentrate would be trucked to the rail load-out facility. Containerizing the concentrate prevents product loss during transit and minimizes environmental problems associated with transporting sulfide minerals.

It is assumed that a suitable tailings pond could be located within a half-mile of the mill. Land area requirements were estimated as follows: for a 5-year mine life - 17 acres per 1,000 stpd mill capacity, for a 10-year mine life - 32 acres per 1,000 stpd mill capacity, and for a 20-year mine life - 62 acres per 1,000 stpd capacity (Ritcey 1989).

The local population in the immediate area would not be sufficient to recruit a work force. The hypothetical mining operation would provide a permanent accommodation complex for the employees. It is assumed employees would work a two-weeks-on, two-weeks-off schedule for the copper skarn mine models. One-third of the employees would be on their scheduled days off at anytime. Two-thirds would be on-site for their scheduled work assignments. Electric power would be produced using diesel powered generators.

As the proposed mine could be accessed from the Dalton Highway, it is assumed that the work force would commute to the mine at their own expense. Initially, employees would commute from communities located in the upper Koyukuk, and also from more distant communities such as Fairbanks. In the long term, it is assumed the population and housing supply would increase in the local communities, but employees would still bear the commuting expense.

Table 8 summarizes the cash flow analysis of the copper skarn mine models. The RMV/st required to achieve a 15% DCFROR ranges from $299/st for a 912 stpd mine to $561/st for a 114 st mine. Figure 9 graphically presents the results for the copper skarn mine models. Table A-18 in Appendix A summarizes the capital and operating costs of the five copper skarn mine models.

Table 8. - Summary of cash flow analysis for copper skarn underground mine models

Deposit size (kst)	Mining rate (stpd)	RMV 15% DCFROR ($/st)
154.3	114	$561
308.6	192	457
617.3	322	387
1,234.6	542	336
2,469.2	912	$299

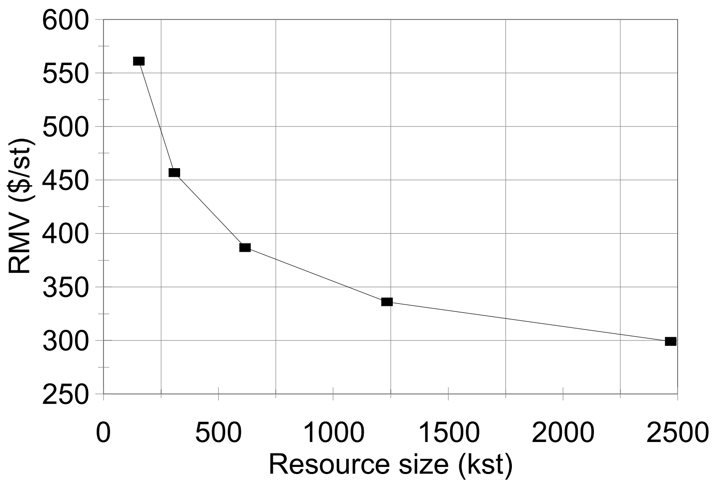


Figure 9. - RMV vs. resource size, copper skarn - underground mine models

Copper Skarn Surface Mine Models

The mine models designed for application to the copper skarn deposit models assume that the structural characteristics of the orebody are such that surface mining methods are applicable. Mineable resource sizes from 154,000 to 2,470,000 st were modeled to represent the possible size for this deposit type. The models are identical to the copper skarn underground mine models, with the exception that the mining method has been changed. It is assumed that the stripping ratio is 4:1 (waste:ore). Surface mining is approximately 20% less expensive than a comparably sized underground operation.

Table 9 summarizes the cash flow analysis of the five copper skarn surface mine models. The RMV required for a 15% DCFROR ranges from $242/st for a 912 stpd mine to $455/st for a 114 stpd mine. Figure 10 graphically presents the results for the copper skarn mine models. Table A-19 in Appendix A summarizes the capital and operating costs of the copper skarn surface mine models.

Table 9. - Summary of cash flow analysis for copper skarn surface mine models

Deposit size (kst)	Mining rate (stpd)	RMV 15% DCFROR ($/st)
154.3	114	$455
308.6	192	368
617.3	322	310
1,234.6	542	270
2,469.2	912	$242

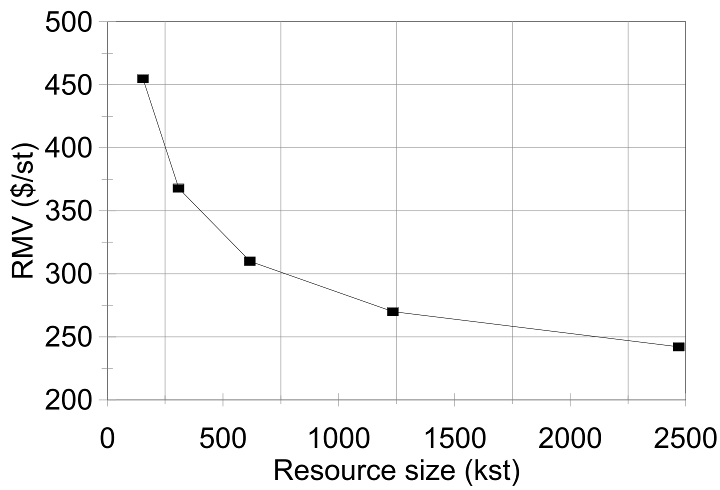


Figure 10. - RMV vs. resource size, copper skarn - surface mine models

Mineralized Quartz Vein Mine Models

The mineralized quartz vein deposit model is based on the geology of mineralized occurrences similar to those found in the Sukakpak Mountain and Vermont Creek areas of the district (Kurtak and others, 1999, p. 19). BLM mineral assessment personnel collected six samples from the Sukakpak averaging 0.59 tr oz/st gold, and twelve samples from the Vermont averaging 0.28 tr oz/st gold (Kurtak and others, 1999, p. 88,104).

The deposit model is described by Cox and Singer (1987) as quartz-carbonate veins with gold and silver associated with base metal sulfides related to hypabyssal intrusions into sedimentary and metamorphic terranes. Mineralogy is native gold and electrum with pyrite, sphalerite, chalcopyrite, galena, arsenopyrite, tetrahedrite-tennantite, silver sulfosalts, argentite, and hematite in veins of quartz, chlorite, calcite, dolomite, and ankerite. Deposits are in areas of high permeability such as intrusive contacts, and/or fault intersections. Replacement ore bodies may form where structures intersect carbonate rocks.

Ten underground vertical crater retreating mine models were developed for application to this deposit model. Two development scenarios are used. In the first development scenario, modeled for five of the mine models, an on-site flotation mill is used to produce concentrates that are shipped out for treatment at a smelter. In the second development scenario, modeled for the other five mine models, it is assumed that high grade ore would be produced that would be acceptable for shipment without preliminary treatment. Under this scenario, no on-site mill is built, which results in significant capital cost savings. However, this savings is partially offset by higher smelting and transportation costs as more material is sent to the smelter.

The Slocan Mining District, British Columbia, Canada contributed nearly 60 percent of the deposit data for Cox and Singer's (1987) base-metal polymetallic vein deposit type model. MINFILE production reports from the Slocan Mining District showed 3.5 Mst mined from 188 deposits from 1892-1997, with an average deposit size of 18,700 st. About 53% of this production was not milled on site, but was of sufficient grade to allow direct shipping of ore to the smelter (British Columbia Ministry of Energy, Mines and Petroleum Resources, 2000).

The mine models designed for application to the mineralized quartz vein deposit models assume that the structural characteristics of the orebody are such that underground mining methods are applicable. Mineable resources sizes from 2,094 to 33,510 st were modeled to represent the possible size for this deposit type.

These are small sized deposits by mining industry standards. Dimensions for the resource size of 2,094 st are estimated at 10 ft thick by 15 ft vertical by 150 ft strike length. The largest resource size of 33,510 st is estimated at 15 ft thick by 66 ft vertical by 374 ft strike length. Mine lives would be short (1.3 to 2.6 years). Due to the short mine lives, the on-site mill models assume the operation would realize some revenue from the salvage value of its equipment when mining is completed.

Equipment appropriate to the size and scale of the modeled operations was selected, including jacklegs, one LHD, freshwater pumps, a backfill pump and mixer, a compressor, and a ventilation fan. The same equipment was adequate to support small scale mining from 4.4 to 36.4 stpd. It is assumed two persons would be employed at the 4.4 stpd mine increasing to nine miners at a 36.4 stpd mine. It is assumed one person would be employed at the 4.4 stpd mill increasing to six persons at a 36.4 stpd mill. Additional shifts would be scheduled to utilize the equipment on more than a one shift per day basis. Appropriately sized travel trailers would be used to house the work force.

Transportation to the hypothetical mine would be provided by a 5 mi road built to connect the operation to the Dalton highway. Containerized concentrate shipments would be trucked approximately 292 mi to Fairbanks. The concentrates would then be transported via the Alaska Railroad approximately 470 mi from Fairbanks to Seward. Concentrates would be shipped year-round to a smelter, assumed to be located in Japan.

Table 10 summarizes the cash flow analysis of the mineralized quartz vein mine models. The RMV required to achieve a 15% DCFROR ranges from $521/st for a 36 stpd mine shipping ore directly to a smelter to $2,688/st for a 4 stpd mine with an on-site mill. Figure 11 graphically presents the results for the mineralized quartz vein models. Tables A-20 and A-21 in Appendix A summarize the capital and operating costs of the ten mineralized quartz vein mine models.

Table 10. - Summary of cash flow analysis for mineralized quartz vein mine models

Deposit size (st)	Mining rate (stpd)	RMV on-site mill 15% DCFROR ($/st)	RMV direct shipping ore 15% DCFROR ($/st)
2,094	4.4	$2,688	$1,596
4,189	7.7	1,627	1,033
8,378	13.2	1,041	752
26,755	22.0	823	635
33,510	36.4	$681	$521

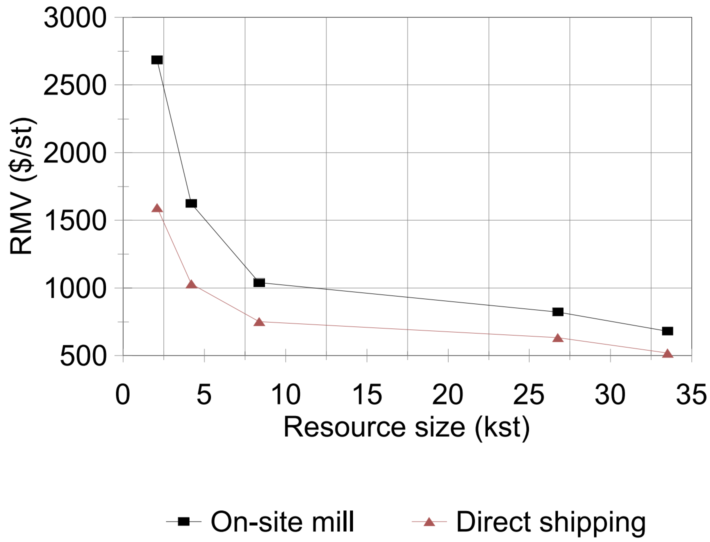


Figure 11. - RMV vs. resource size, mineralized quartz vein mine models

Massive Sulfide Mine Models

The massive sulfide deposit model is based on the geology of a mineralized occurrence in the Koyukuk mining district. The deposit model is described by Cox and Singer (1987) as thin, sheetlike bodies of massive to well-laminated pyrite, pyrrhotite, and chalcopyrite within thinly laminated clastic sediments and mafic tuffs. Mineralogy is pyrite, pyrrhotite, chalcopyrite, sphalerite, magnetite, valleriite, galena, bornite, tetrahedrite, cobaltite, cubanite, stannnite, molybdenite, quartz, carbonate, albite, white mica, chlorite, amphibole, and tourmaline. Deposits have uncertain ore controls but are thin, usually laterally extensive and tend to cluster in an en echelon pattern.

The mine models designed for the deposit model assumes that the structural characteristics of the orebody are such that underground room and pillar mining methods are applicable. Mineable resource sizes from 60,600 to 970,000 st were modeled.

Transportation to the hypothetical mine would be provided by a 22 mi road built to join the operation to the Dalton Highway. A concentrate load out facility in Fairbanks would be built to handle containerized copper concentrate shipments to Seward, Alaska. The approximate rail haulage distance is about 470 miles one way.

A new marine terminal and ship loading facility in Seward would be built to handle the mine's containerized copper concentrates. The facility would share some of the existing terminal's infrastructure currently utilized by the Seward coal terminal, which handles coal from the Usibelli coal mine operation near Healy, Alaska.

It is assumed that the mine operator would retain the services of a commercial stevedoring firm to handle receiving, mineral concentrate storage, reclaiming, and shiploading. A trucking firm would handle both incoming supplies and fuel delivery to the mine and outgoing mineral concentrate shipments for the majority of the mine's shipping needs. Concentrates would be shipped year-round to a smelter, assumed to be located in Japan.

Five underground room and pillar mine models were developed for application to this deposit model. In each mine model, the associated mill uses one product flotation to process the ore. One concentrate storage building at the mill-site capable of storing six weeks of concentrate was assumed. Containerized concentrate would be trucked to the rail load out facility. Containerizing the concentrate prevents product loss during transit and minimizes environmental problems associated with transporting sulfide minerals.

The local population in the immediate area would not be sufficient to recruit a work force. The hypothetical mining operation would provide a permanent accommodation complex for the employees. It is assumed employees would work a two-weeks-on, two-weeks-off schedule for the massive sulfide mine models. One-third of the employees would be on their scheduled days off at anytime. Two-thirds would be on-site for their scheduled work assignments. The massive sulfide mine models would produce their own electric power using diesel powered generators.

As the proposed mine could be accessed from the Dalton Highway, it is assumed that the work force would commute to the mine at their own expense. Initially, employees would commute from communities located in the upper Koyukuk, and also from more distant communities such as Fairbanks. In the long term, it is assumed the population and housing supply would increase in the local communities, but employees would still bear the commuting expense.

It is assumed that a suitable tailings pond could be located within a half-mile of the mill. Land area requirements were estimated as follows: for a 5-year mine life - 17 acres per 1,000 stpd mill capacity, for a 10-year mine life - 32 acres per 1,000 stpd mill capacity, and for a 20-year mine life - 62 acres per 1,000 stpd capacity (Ritcey 1989).

Table 11 summarizes the cash flow analysis of the massive sulfide models. The RMV required to achieve a 15% DCFROR ranges from $344/st for a 452 stpd air-supported mine to $832/st for a 56 stpd mine supported by a 20 mi road. Figure 12 graphically presents the results for the massive sulfide mine models. Tables A-22 and A-23 in Appendix A summarizes the capital and operating costs of the ten massive sulfide mine models.

Table 11. - Summary of cash flow analysis for massive sulfide mine models

Deposit size (kst)	Mining rate (stpd)	RMV 15% DCFROR ($/st) 20-mile road	RMV 15% DCFROR ($/st) 200 miles air access
60.6	56	$832	$785
121.2	95	636	623
242.5	160	512	484
485.0	269	430	404
970.0	452	$368	$344

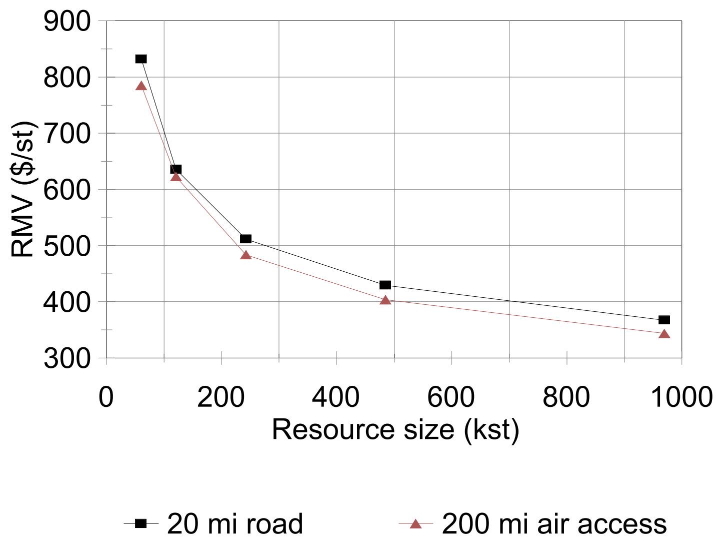


Figure 12. - RMV vs. resource size, massive sulfide mine models

SUMMARY AND CONCLUSIONS

Economic mining prefeasibility investigations were conducted for placer gold, porphyry copper, copper skarn, mineralized quartz vein, and massive sulfide deposit types found in the Koyukuk Mining District. Mine models were developed for mineral deposit models described by Cox and Singer (1987). Capital and operating costs for the models were determined using the USBM's CES (U.S. Bureau of Mines, 1995). Published cost information drawn from industry publications, permitting documents, and environmental impact statements were also used. All costs were escalated by factors that reflect the higher cost of labor, transportation, and electricity in Alaska.

The cost data for each mine model were used to perform a cash flow analysis for each mine model, and the DCFROR was calculated. The goal of the prefeasibility study was to determine the RMV/st or RMV/lcy of mineable ore that would provide a 15% DCFROR for each mine model. Results are summarized in Tables 12 and 13.

Table 12. - Summary of placer model results

Model	RMV range - 15% DCFROR	
	RMV at 1,941 lcy/d ($/lcy)	RMV at 243 lcy/d ($/lcy)
Surface placer (10 mi road)	$4.23	$18.43
Surface placer (50 mi road)	4.84	25.49
Surface placer (100 mi road)	5.63	35.05
Surface placer (200 mi air access)	4.62	18.35
Surface placer (10 mi winter trail)	4.11	16.82
Surface placer (50 mi winter trail)	4.18	17.61
Surface placer (100 mi winter trail)	4.30	18.55
Underground placer (10 mi road)	6.41	19.73
Underground placer (50 mi road)	7.04	26.82
Underground placer (100 mi road)	7.82	36.04
Underground placer (200 mi air access)	6.33	18.19
Underground placer (10 mi winter trail)	6.28	18.19
Underground placer (50 mi winter trail)	6.37	18.66
Underground placer (100 mi winter trail)	6.51	19.99
Incremental RMV needed to add backhoe	$0.25	$2.18

Table 13. - Summary of hard rock model results

Model	RMV range - 15% DCFROR			
	low ($/st)	capacity (stpd)	high ($/st)	capacity (stpd)
Copper porphyry	$37	31,309	$90	3,913
Copper skarn underground	299	912	561	114
Copper skarn surface	242	912	455	114
Mineralized quartz vein (on-site mill)	538	36	2,688	4
Mineralized quartz vein (direct ship ore)	502	36	1,596	4
Massive sulfide	$368	452	$832	56

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APPENDIX A. - CAPITAL AND OPERATING COSTS FOR MINE MODELS

The tables in this appendix give the mineral deposit type and mine model descriptions; and capital and operating costs for the Koyukuk Mining District models. Capital costs are categorized into six groups which may include acquisition, exploration, infrastructure, mine, mill, reclamation, and working capital costs for each model. Operating costs are categorized into six groups which may include general and administrative, infrastructure, mine, mill, smelting, and transportation.

A two-year preproduction period is assumed for the placer models. The models assume exploration, permitting, development, mobilization, and construction will take two years. All activities would operate concurrently during the two-year period (2001-2002). Production would begin in 2003 on a seasonal basis. Reclamation would commence in the final year of production immediately following depletion of the deposit.

Table A-1. - Placer gold mine model descriptions

Deposit size (lcy)	Mine model	Mining rate (lcy/d)	Mine life (yrs)[3]	Mill type
179,850	Surface	243	4	Gravity
359,700	Surface	408	5	Gravity
719,400	Surface	686	6	Gravity
1,438,800	Surface	1,154	7	Gravity
2,877,600	Surface	1,941	8	Gravity
179,850	Room and pillar	243	4	Gravity
359,700	Room and pillar	408	5	Gravity
719,400	Room and pillar	686	6	Gravity
1,438,800	Room and pillar	1,154	7	Gravity
2,877,600	Room and pillar	1,941	8	Gravity

[3] Mine life estimate is based on 180 days per year operating 10 hours/day.

A four-year pre-production period is assumed for the copper porphyry, copper skarn, quartz vein, and massive sulfide models. The models assume exploration, permitting, development, mobilization, and construction will take four years. All activities would operate concurrently during the four year period (2001-2004). Production would begin in 2005. Reclamation would commence in the final year of production immediately following depletion of the deposit.

Table A-2. - Mine model descriptions

Deposit type	Deposit size (st)	Mine model	Mining rate (stpd)	Mine life (yrs)[4]	Mill type
Copper porphyry	15,625,000	Surface	3,913	12.6	Flotation
Copper porphyry	31,250,000	Surface	6,582	15.0	Flotation
Copper porphyry	62,500,000	Surface	11,069	17.8	Flotation
Copper porphyry	125,000,000	Surface	18,616	21.2	Flotation
Copper porphyry	250,000,000	Surface	31,309	25.2	Flotation
Copper skarn	154,300	Surface/Underground	114	3.9	Flotation
Copper skarn	308,600	Surface/Underground	192	4.6	Flotation
Copper skarn	617,300	Surface/Underground	322	5.5	Flotation
Copper skarn	1,234,600	Surface/Underground	542	6.5	Flotation
Copper skarn	2,469,200	Surface/Underground	912	7.7	Flotation
Quartz vein	1,900	Vertical crater retreating	4.4	1.3	Flotation
Quartz vein	3,800	Vertical crater retreating	7.7	1.6	Flotation
Quartz vein	7,600	Vertical crater retreating	13.2	1.9	Flotation
Quartz vein	15,200	Vertical crater retreating	22.0	2.2	Flotation
Quartz vein	30,400	Vertical crater retreating	36.4	2.6	Flotation
Massive sulfide	60,600	Room and pillar	56	3.1	Flotation
Massive sulfide	121,300	Room and pillar	95	3.6	Flotation
Massive sulfide	242,500	Room and pillar	160	4.3	Flotation
Massive sulfide	485,000	Room and pillar	269	5.2	Flotation
Massive sulfide	970,000	Room and pillar	452	6.1	Flotation

[4] Mine life estimate is based on 350 days per year.

TABLE A-3. - Capital and operating costs - surface gold placer model road supported operation (10 mi road)

Model description					
Resource size (klcy)	179.8	359.7	719.4	1,438.8	2,877.6
Mining rate (lcy/d)	243	408	686	1,154	1,941
Capital costs ($ thousands)					
Acquisition & exploration	99.2	184.8	349.1	662.0	1,258.2
Infrastructure	324.6	345.5	375.8	413.1	468.7
Mine	105.7	158.1	235.1	348.5	523.8
Reclamation	35.5	43.2	56.2	78.6	118.7
Working capital	95.0	108.0	124.0	146.0	176.0
TOTAL	660.0	839.6	1,140.2	1,648.2	2,545.4
Operating costs ($/lcy)					
Infrastructure	1.97	1.58	1.31	1.10	0.94
Mine	9.08	5.77	3.75	2.49	1.65
Mill	2.14	1.40	0.94	0.65	.43
TOTAL	13.19	8.76	6.00	4.24	3.03

TABLE A-4. - Capital and operating costs - surface gold placer model road supported operation (50 mi road)

Model description					
Resource size (klcy)	179.8	359.7	719.4	1,438.8	2,877.6
Mining rate (lcy/d)	243	408	686	1,154	1,941
Capital costs ($ thousands)					
Acquisition & exploration	99.2	184.8	349.1	662.0	1,258.2
Infrastructure	1,050.3	1,071.2	1,101.5	1,138.8	1,194.4
Mine	105.7	158.1	235.1	348.5	523.8
Reclamation	186.7	200.4	223.5	262.3	330.9
Working capital	101.0	114.0	130.0	152.0	182.0
TOTAL	1,542.9	1,728.5	2,039.2	2,563.6	3,489.3
Operating costs ($/lcy)					
Infrastructure	2.81	2.07	1.60	1.28	1.05
Mine	9.08	5.77	3.75	2.49	1.65
Mill	2.14	1.40	0.94	0.65	.43
TOTAL	14.03	9.25	6.29	4.41	3.13

TABLE A-5. - Capital and operating costs - surface gold placer model road supported operation (100 mi road)

Model description					
Resource size (klcy)	179.8	359.7	719.4	1,438.8	2,877.6
Mining rate (lcy/d)	243	408	686	1,154	1,941
Capital costs ($ thousands)					
Acquisition & exploration	99.2	184.8	349.1	662.0	1,258.2
Infrastructure	1,956.6	1,977.5	2,007.8	2,045.1	2,100.7
Mine	105.7	158.1	235.1	348.5	523.8
Reclamation	353.8	368.6	393.5	435.4	509.5
Working capital	109.0	121.0	138.0	160.0	190.0
TOTAL	2,624.3	2,810.0	3,123.5	3,651.0	4,582.2
Operating costs ($/lcy)					
Infrastructure	3.86	2.69	1.96	1.50	1.18
Mine	9.08	5.77	3.75	2.49	1.65
Mill	2.14	1.40	0.94	0.65	0.43
TOTAL	15.08	9.86	6.66	4.63	3.26

TABLE A-6. - Capital and operating costs - surface gold placer model air supported operation

Model description					
Resource size (klcy)	179.8	359.7	719.4	1,438.8	2,877.6
Mining rate (lcy/d)	243	408	686	1,154	1,941
Capital costs ($ thousands)					
Acquisition & exploration	128.0	211.5	365.0	664.6	1,217.6
Infrastructure	180.4	202.4	231.4	268.4	323.4
Mine	106.4	158.4	235.5	348.5	523.7
Reclamation	36.0	43.0	56.0	79.0	96.0
Working capital	103.1	116.5	136.4	166.5	205.6
TOTAL	553.9	731.8	1,024.3	1,527.0	2,366.3
Operating costs ($/lcy)					
Infrastructure	2.64	2.14	1.78	1.56	1.37
Mine	9.23	5.88	3.83	2.54	1.68
Mill	2.28	1.51	1.02	0.71	0.49
TOTAL	14.15	9.53	6.63	4.81	3.54

TABLE A-7. - Capital and operating costs - surface gold placer model road supported operation (10 mi winter trail)

Model description					
Resource Size (klcy)	179.8	359.7	719.4	1,438.8	2,877.6
Mining rate (lcy/d)	243	408	686	1,154	1,941
Capital costs ($ thousands)					
Acquisition & exploration	99.2	184.8	349.1	662.0	1,258.2
Infrastructure	149.5	170.4	200.7	238.0	293.6
Mine	105.7	158.1	235.1	348.5	523.8
Reclamation	35.5	43.2	56.2	78.6	118.7
Working capital	94.6	107.3	123.8	145.8	175.8
TOTAL	484.5	663.8	964.9	1,472.9	2,370.1
Operating costs ($/lcy)					
Infrastructure	1.91	1.55	1.28	1.09	0.94
Mine	9.08	5.77	3.75	2.49	1.65
Mill	2.14	1.40	0.94	0.65	0.43
TOTAL	13.13	8.72	5.98	4.22	3.02

TABLE A-8. - Capital and operating costs - surface gold placer model road supported operation (50 mi winter trail)

Model description					
Resource size (klcy)	179.8	359.7	719.4	1,438.8	2,877.6
Mining rate (lcy/d)	243	408	686	1,154	1,941
Capital costs ($ thousands)					
Acquisition & exploration	99.2	184.8	349.1	662.0	1,258.2
Infrastructure	174.2	195.1	225.4	262.7	318.3
Mine	105.7	158.1	235.1	348.5	523.8
Reclamation	38.2	52.0	75.0	113.9	182.4
Working capital	98.8	111.6	128.1	150.0	180.1
TOTAL	516.1	701.6	1,012.7	1,537.1	2,462.8
Operating costs ($/lcy)					
Infrastructure	2.50	1.89	1.49	1.21	1.01
Mine	9.08	5.77	3.75	2.49	1.65
Mill	2.14	1.40	0.94	0.65	0.43
TOTAL	13.73	9.07	6.19	4.35	3.09

TABLE A-9. - Capital and operating costs - surface gold placer model road supported operation (100 mi winter trail)

Model description					
Resource size (klcy)	179.8	359.7	719.4	1,438.8	2,877.6
Mining rate (lcy/d)	243	408	686	1,154	1,941
Capital costs ($ thousands)					
Acquisition & exploration	99.2	184.8	349.1	662.0	1,258.2
Infrastructure	205.0	225.9	256.2	293.5	349.1
Mine	105.7	158.1	235.1	348.5	523.8
Reclamation	41.1	54.9	77.9	116.8	185.3
Working capital	104.2	116.9	133.4	155.4	185.4
TOTAL	555.2	740.6	1,051.7	1,576.2	2,501.8
Operating costs ($/lcy)					
Infrastructure	3.25	2.33	1.75	1.37	1.10
Mine	9.08	5.77	3.75	2.49	1.65
Mill	2.14	1.40	0.94	0.65	0.43
TOTAL	14.47	9.50	6.44	4.51	3.19

TABLE A-10. - Capital and operating costs - underground placer road supported operation (10 mi pioneer road)

Model description					
Resource size (klcy)	179.8	359.7	719.4	1,438.8	2,877.6
Mining rate (lcy/d)	243	408	686	1,154	1,941
Capital costs ($ thousands)					
Acquisition & exploration	114.9	183.8	302.7	529.4	929.0
Infrastructure	409.4	527.2	706.6	991.9	1,519.7
Mine	240.9	307.5	418.1	602.3	910.3
Reclamation	67.4	90.4	127.3	189.5	298.4
Working capital	91.8	115.2	145.6	186.6	252.4
TOTAL	924.4	1,224.1	1,700.3	2,499.7	3,909.8
Operating costs ($/lcy)					
Infrastructure	0.56	0.38	0.27	0.20	0.15
Mine	10.10	7.77	5.95	4.61	3.80
Mill	1.93	1.26	0.85	0.58	0.39
TOTAL	12.59	9.41	7.07	5.39	4.33

TABLE A-11. - Capital and operating costs - underground placer road supported operation (50 mi pioneer road)

Model description					
Resource size (klcy)	179.8	359.7	719.4	1,438.8	2,877.6
Mining rate (lcy/d)	243	408	686	1,154	1,941
Capital costs ($ thousands)					
Acquisition & exploration	114.9	183.8	302.7	529.4	929.0
Infrastructure	1,135.1	1,252.9	1,432.3	1,717.6	2,245.4
Mine	240.9	307.5	418.1	602.3	910.3
Reclamation	125.9	148.9	185.8	248.1	356.9
Working capital	97.8	121.2	151.6	192.6	258.4
TOTAL	1,714.6	2,014.3	2,490.5	3,290.0	4,700.0
Operating costs ($/lcy)					
Infrastructure	1.39	0.87	0.57	0.37	0.25
Mine	10.10	7.77	5.95	4.61	3.80
Mill	1.93	1.26	0.85	0.58	0.39
TOTAL	13.42	9.91	7.37	5.56	4.44

TABLE A-12. - Capital and operating costs - underground placer road supported operation (100 mi pioneer road)

Model description					
Resource size (klcy)	179.8	359.7	719.4	1,438.8	2,877.6
Mining rate (lcy/d)	243	408	686	1,154	1,941
Capital costs ($ thousands)					
Acquisition & exploration	114.9	183.8	302.7	529.4	929.0
Infrastructure	2,041.4	2,159.2	2,338.6	2,623.9	3,151.7
Mine	240.9	307.5	418.1	602.3	910.3
Reclamation	199.0	222.0	258.9	321.3	430.0
Working capital	105.4	128.8	159.2	200.2	266.0
TOTAL	2,701.6	3,001.3	3,477.5	4,277.0	5,687.0
Operating costs ($/lcy)					
Infrastructure	2.42	1.49	0.93	0.59	0.38
Mine	10.10	7.77	5.95	4.61	3.80
Mill	1.93	1.26	0.85	0.58	0.39
TOTAL	14.45	10.52	7.73	5.78	4.57

TABLE A-13. - Capital and operating costs - underground placer air supported operation

Model description					
Resource size (klcy)	179.8	359.7	719.4	1,438.8	2,877.6
Mining rate (lcy/d)	243	408	686	1,154	1,941
Capital costs ($ thousands)					
Acquisition & exploration	114.9	183.8	302.7	529.4	929.0
Infrastructure	265.5	383.3	562.7	848.0	1,375.8
Mine	240.9	307.5	418.1	602.3	910.3
Reclamation	55.8	78.8	115.7	178.0	287.0
Working capital	97.9	123.7	157.7	205.6	281.5
TOTAL	775.0	1,077.1	1,556.9	2,363.3	3,783.6
Operating costs ($/lcy)					
Infrastructure	1.40	1.08	0.86	0.75	0.65
Mine	10.10	7.77	5.95	4.61	3.80
Mill	1.93	1.26	0.85	0.58	0.39
TOTAL	13.43	10.11	7.66	5.94	4.83

TABLE A-14. - Capital and operating costs - underground placer road supported operation (10 mi winter trail)

Model description					
Resource size (klcy)	179.8	359.7	719.4	1,438.8	2,877.6
Mining rate (lcy/d)	243	408	686	1,154	1,941
Capital costs ($ thousands)					
Acquisition & exploration	114.9	183.8	302.7	529.4	929.0
Infrastructure	234.3	352.1	531.5	816.8	1,344.6
Mine	240.9	307.5	418.1	602.3	910.3
Reclamation	54.5	76.7	111.8	170.8	274.9
Working capital	91.3	114.8	145.1	186.1	251.9
TOTAL	735.9	1,034.9	1,509.2	2,305.4	3,710.7
Operating costs ($/lcy)					
Infrastructure	0.50	0.34	0.25	0.19	0.14
Mine	10.10	7.77	5.95	4.61	3.80
Mill	1.93	1.26	0.85	0.58	0.39
TOTAL	12.53	9.38	7.05	5.38	4.33

TABLE A-15. - Capital and operating costs - underground placer road supported operation (50 mi winter trail)

Model description					
Resource size (klcy)	179.8	359.7	719.4	1,438.8	2,877.6
Mining rate (lcy/d)	243	408	686	1,154	1,941
Capital costs ($ thousands)					
Acquisition & exploration	114.9	183.8	302.7	529.4	929.0
Infrastructure	259.0	376.8	556.2	841.5	1,369.3
Mine	240.9	307.5	418.1	602.3	910.3
Reclamation	56.8	79.0	114.1	173.1	277.2
Working capital	95.6	119.0	149.4	190.4	256.2
TOTAL	767.2	1,066.1	1,540.5	2,336.7	3,742.0
Operating costs ($/lcy)					
Infrastructure	1.09	0.69	0.46	0.31	0.21
Mine	10.10	7.77	5.95	4.61	3.80
Mill	1.93	1.26	0.85	0.58	0.39
TOTAL	13.11	9.73	7.26	5.50	4.40

TABLE A-16. - Capital and operating costs - underground placer road supported operation (100 mi winter trail)

Model description					
Resource size (klcy)	179.8	359.7	719.4	1,438.8	2,877.6
Mining rate (lcy/d)	243	408	686	1,154	1,941
Capital costs ($ thousands)					
Acquisition & exploration	114.9	183.8	302.7	529.4	929.0
Infrastructure	289.8	407.6	587.0	872.3	1,400.1
Mine	240.9	307.5	418.1	602.3	910.3
Reclamation	59.7	81.9	117.0	176.0	280.1
Working capital	101.0	124.4	154.8	195.8	261.6
TOTAL	806.3	1,105.2	1,579.6	2,375.8	3,781.1
Operating costs ($/lcy)					
Infrastructure	1.82	1.13	0.72	0.46	0.30
Mine	10.10	7.77	5.95	4.61	3.80
Mill	1.93	1.26	0.85	0.58	0.39
TOTAL	13.85	10.16	7.52	5.65	4.49

TABLE A-17. - Capital and operating costs - copper porphyry mine models

Model description					
Resource size (Mst)	17	34	68	138	276
Mining rate (stpd)	3,913	6,582	11,069	18,616	31,309
Capital costs ($ millions)					
Acquisition	7.99	11.20	14.42	22.58	33.26
Exploration	19.98	25.66	36.04	56.44	83.15
Infrastructure	90.82	99.76	114.23	141.02	183.05
Mine	57.43	80.35	123.70	198.30	323.04
Mill	32.29	53.51	89.58	156.38	257.88
Working capital	19.46	24.95	33.56	47.23	69.22
Reclamation	15.98	20.53	28.83	42.26	66.52
TOTAL	243.95	315.96	440.36	664.21	1,016.12
Operating costs ($/st)					
Mine	8.89	7.61	6.68	6.02	5.56
Mill	16.61	13.64	11.44	9.90	8.75
Smelting	5.26	5.26	5.26	5.26	5.26
Transportation	18.04	11.48	7.57	5.25	3.87
TOTAL	48.80	37.99	30.95	26.43	23.44

TABLE A-18. - Capital and operating costs - copper skarn underground mine models

Model description					
Resource size (kst)	154.3	308.6	617.3	1,234.6	2,469.2
Mining rate (stpd)	114	192	322	542	912
Capital costs ($ millions)					
Acquisition	0.88	1.19	1.66	2.37	3.47
Exploration	2.65	3.59	4.98	7.10	10.41
Infrastructure	3.13	5.23	8.98	15.65	27.70
Mine	7.77	10.29	13.61	18.04	23.92
Mill	9.03	11.00	13.44	16.56	20.55
Working capital	1.77	2.40	3.32	4.73	6.94
Reclamation	3.12	4.77	7.36	11.58	18.39
TOTAL	28.35	38.47	55.35	76.03	111.38
Operating costs ($/st)					
Mine	77.04	63.23	52.12	43.00	35.61
Mill	55.83	40.39	29.52	21.66	16.02
Smelting	101.46	101.46	101.46	101.46	101.46
Transportation	71.22	71.12	71.06	71.03	71.01
TOTAL	305.55	276.19	254.16	237.15	224.09

TABLE A-19. - Capital and operating costs - copper skarn surface mine models

Model description					
Resource size (kst)	154.3	308.6	617.3	1,234.6	2,469.2
Mining rate (stpd)	114	192	322	542	912
Capital costs ($ millions)					
Acquisition	0.62	0.80	1.06	1.43	2.00
Exploration	1.86	2.40	3.18	4.30	6.03
Infrastructure	2.39	3.87	6.45	10.96	18.99
Mine	5.74	7.11	8.95	11.17	14.13
Mill	6.84	8.33	10.17	12.51	15.50
Working capital	1.24	1.60	2.12	2.87	4.02
Reclamation	2.72	4.10	6.28	9.85	15.64
TOTAL	21.41	28.21	38.21	53.09	76.31
Operating costs ($/st)					
Mine	58.44	44.43	34.01	26.07	20.08
Mill	51.04	36.58	26.47	19.21	14.06
Smelting	92.04	92.04	92.04	92.04	92.04
Transportation	64.39	64.39	64.39	64.39	64.39
TOTAL	265.92	237.44	216.91	201.72	190.57

TABLE A-20. - Capital and operating costs - mineralized quartz vein models on-site mill models

Model description					
Resource size (st)	2,094	4,189	8,378	16,755	33,510
Mining rate (stpd)	4.4	7.7	13.2	22.0	36.4
Capital costs ($ thousands)					
Acquisition	235.1	305.4	409.8	567.2	812.0
Exploration	53.7	53.7	53.7	53.7	53.7
Infrastructure	236.0	244.7	254.9	266.7	280.6
Mine	849.6	877.3	931.0	983.4	1,048.3
Mill	2,979.6	3,609.7	4,351.2	5,204.9	6,218.6
Working capital	333.8	452.8	645.0	914.0	1,725.6
Reclamation	499.5	649.0	870.8	1,205.3	1,302.2
TOTAL	5,187.3	6,192.6	7,516.4	9,195.2	11,441.2
Operating costs ($/st)					
Mine	343.25	242.78	192.36	150.02	113.40
Mill	343.97	235.96	164.80	117.75	85.05
Smelting	101.46	101.46	101.46	101.46	101.46
Transportation	138.55	138.55	138.55	138.55	138.55
TOTAL	927.23	718.75	597.17	507.78	438.46

TABLE A-21. - Capital and Operating costs - mineralized quartz vein models direct shipping ore models

Model description					
Resource size (st)	2,094	4,189	8,378	16,755	33,510
Mining rate (stpd)	4.4	7.72	13.23	22.05	36.38
Capital costs ($ thousands)					
Acquisition	235.1	305.4	409.8	567.2	812.0
Exploration	53.7	53.7	53.7	53.7	53.7
Infrastructure	236.0	244.7	254.9	266.7	280.6
Mine	849.6	877.3	931.0	983.4	1,048.3
Working capital	271.8	405.9	635.6	975.4	1,489.3
Reclamation	499.5	649.0	870.8	1,205.3	1,725.6
TOTAL	2,145.7	2,536.0	3,155.8	4,051.7	5,409.5
Operating costs ($/st)					
Mine	343.25	242.78	192.36	150.02	113.40
Smelting	202.92	202.92	202.92	202.92	202.92
Transportation	138.55	138.55	138.55	138.55	138.55
TOTAL	684.72	584.25	533.83	491.49	454.87

TABLE A-22. - Capital and Operating costs - massive sulfide models 20 mi road

Model description					
Resource size (kst)	60.6	121.2	242.5	485.0	970.0
Mining rate (stpd)	56	95	160	269	452
Capital costs ($ millions)					
Acquisition	0.63	0.83	1.11	1.52	2.14
Exploration	1.90	2.49	3.33	4.56	6.42
Infrastructure	1.99	2.83	4.36	7.10	12.06
Mine	5.34	7.05	9.33	12.35	16.35
Mill	6.98	8.44	10.26	12.53	15.38
Working capital	1.93	2.89	4.40	6.82	10.69
Reclamation	1.27	1.66	2.22	3.04	4.28
TOTAL	20.04	26.19	35.01	47.92	67.32
Operating costs ($/st)					
Mine	100.69	82.50	67.71	55.72	45.98
Mill	86.95	62.49	45.17	32.88	24.11
Smelting	101.46	101.46	101.46	101.46	101.46
Transportation	93.03	92.25	91.79	91.51	91.35
TOTAL	382.13	338.70	306.13	281.58	262.90

TABLE A-23. - Capital and Operating costs - massive sulfide models
200 mi air access

Model description					
Resource size (kst)	60.6	121.2	242.5	485.0	970.0
Mining rate (stpd)	56	95	160	269	452
Capital costs ($ millions)					
Acquisition	0.60	0.80	1.07	1.47	2.08
Exploration	1.81	2.39	3.21	4.42	6.23
Infrastructure	1.32	2.15	3.68	6.42	11.38
Mine	5.34	7.05	9.33	12.35	16.35
Mill	6.98	8.44	10.26	12.53	15.38
Working capital	1.82	2.70	2.14	2.94	4.16
Reclamation	1.21	1.59	4.09	6.30	9.84
TOTAL	19.08	25.12	33.78	46.43	65.42
Operating costs ($/st)					
Mine	100.69	82.50	67.71	55.72	45.98
Mill	86.95	62.49	45.17	32.88	24.11
Smelting	101.46	101.46	101.46	101.46	101.46
Transportation	70.30	70.29	70.29	70.28	70.28
TOTAL	359.40	316.74	284.63	260.35	241.83

Tables A-24 to A-30 can be used to estimate the average RMV needed for a year round placer operation. For example, a placer mine operation supported by a 10 mi road mines 686 lcy/d with a surface operation during the summer, and 408 lcy/d with an underground operation during the winter. Refer to Table A-24, select the surface mining rate of 686 lcy/d from the lefthand column and 408 lcy/d from the U/G model mining rate in the second row of the table. The RMV can be found at the intersection of this row and column and is $10/lcy.

Table A-24. - Summary of RMV - combination of underground (U/G) and surface gold placer mine models
10 mi road

Surface model mining rate (lcy/d)	U/G model mining rate (lcy/d)				
	243	408	686	1,154	1,904
	RMV - 15% DCFROR ($/lcy)				
243	19	16	12	9	7
408	15	13	11	9	7
686	11	10	9	8	7
1,154	8	8	8	7	6
1,904	5	5	6	6	5

Table A-25. - Summary of RMV - combination of underground (U/G) and surface gold placer mine models 50 mi road

Surface model mining rate (lcy/d)	U/G model mining rate (lcy/d)				
	243	408	686	1,154	1,904
	RMV - 15% DCFROR ($/lcy)				
243	26	21	15	11	8
408	20	17	14	11	8
686	14	13	12	10	8
1,154	9	9	9	8	7
1,904	6	6	6	6	6

Table A-26. - Summary of RMV - combination of underground (U/G) and surface gold placer mine models - 100 mi road

Surface model mining rate (lcy/d)	U/G model mining rate (lcy/d)				
	243	408	686	1,154	1,904
	RMV - 15% DCFROR ($/lcy)				
243	36	27	19	13	9
408	26	22	17	13	9
686	18	17	14	12	9
1,154	12	12	11	10	8
1,904	7	8	8	7	7

Table A-27. - Summary of RMV - combination of underground (U/G) and surface gold placer mine models - 200 mi air access

Surface model mining rate (lcy/d)	U/G model mining rate (lcy/d)				
	243	408	686	1,154	1,904
	RMV - 15% DCFROR ($/lcy)				
243	19	16	12	10	7
408	15	14	11	9	7
686	11	11	10	9	7
1,154	7	8	8	7	6
1,904	5	6	6	6	6

Table A-28. - Summary of RMV - combination of underground (U/G) and surface gold placer mine models 10 mi winter trail

Surface model mining rate (lcy/d)	U/G model mining rate (lcy/d)				
	243	408	686	1,154	1,904
	RMV - 15% DCFROR ($/lcy)				
243	18	15	12	9	7
408	14	12	11	9	7
686	10	10	9	8	7
1,154	7	4	7	7	6
1,904	5	5	5	5	5

Table A-29. - Summary of RMV - combination of underground (U/G) and surface gold placer mine models 50 mi winter trail

Surface model mining rate (lcy/d)	U/G model mining rate (lcy/d)				
	243	408	686	1,154	1,904
	RMV - 15% DCFROR ($/lcy)				
243	18	14	10	7	5
408	15	13	10	8	5
686	12	11	9	7	5
1,154	9	9	8	7	5
1,904	7	7	7	6	5

Table A-30. - Summary of RMV - combination of underground (U/G) and surface gold placer mine models 100 mi winter trail

Surface model mining rate (lcy/d)	U/G model mining rate (lcy/d)				
	243	408	686	1,154	1,904
	RMV - 15% DCFROR ($/lcy)				
243	19	15	11	8	5
408	16	14	11	8	5
686	12	11	10	8	6
1,154	9	9	8	7	6
1,904	7	7	7	6	5

APPENDIX B. - ECONOMIC ASSUMPTIONS

This appendix includes information regarding the development of the economic models. It notes all major assumptions for income tax rates, depletion, depreciation, commodity prices, exploration and permitting costs, working capital, salvage value, and reclamation expense.

It is important to emphasize that the mine models described in this report are based on hypothetical mining and milling scenarios. The models are not meant to represent a feasibility analysis of specific deposits. This would be inappropriate since such an analysis requires more precise data than that available for this report. The models are based on order-of-magnitude estimates. The American Association of Cost Engineers, an association of cost engineers and related personnel, has established the following classification scheme for cost estimates.

Type of estimate	Accuracy
Order-of-magnitude estimate	-30% +50%
Preliminary estimate	-15% +30%
Definitive estimate	- 5% +15%

The models do not include proprietary company data which, if available, would probably change the outcome of the evaluation. When applicable, cost information from developing or producing mines in Alaska was used in constructing the models. Alaska Mineral Industry Cost Escalation Factors (AMICEF) of 1.49 for operating labor, 1.58 for capital labor, 1.15 for capital costs, and 1.60 for electricity were used to reflect higher costs in the Koyukuk Mining District. These factors are a set of calculated values that are used to escalate itemized capital and operating costs for mining and milling operations from the central front range of the Rocky Mountains (Denver vicinity) to any point in Alaska (Balen and Allen, 1993).

A number of factors control the feasibility of mineral development, including physical attributes of the deposit, metallurgical attributes of the ores, metal markets, infrastructure availability, political climate, environmental constraints, and corporate policy. Any forecast of the development potential should weigh all of these factors.

Cash Flow Assumptions

All RMV ($/st) are equal to the amount of revenues required before all expenses including royalties, mining and milling capital and operating costs, off-site transportation costs, base smelting charges, and taxes are deducted. Base smelter charges are estimated at $203/st for copper concentrate. RMV includes smelter recovery and all price and assay adjustments which reduce the smelter payment (Schumacher, 2000). It is assumed all concentrates would be sent to Japan.

Federal income tax, Alaska corporate income tax, mining license tax rates and the effects of the exploration incentive credits toward future tax and royalty obligations due the State of Alaska are simulated with a 40% tax rate. All projects were assumed to be equity financed and Modified Accelerated Cost Recovery System (ACRS) depreciation and percentage depletion were utilized in the cash flow calculations.

Exploration costs were considered for all models. Acquisition capital cost represent the direct cost of permitting, and were estimated at 4% of the total project cost (Sherman, 1990). Reclamation costs were included in the models. Mine and mill reinvestment were not considered for models. Working capital for placer gold mine models equals 30 days of operating costs, and is recovered in the last year of the project for purposes of the cash flow calculations.

Calculation of RMV

Assume mill feed with grades of 11% zinc, 396.5 g/mt silver, 3% lead, and 3.6 g/mt gold was mined from a deposit. Mill recoveries were estimated at 90% for zinc, 85% for silver, 81% for lead, and 71% for gold. Smelter recoveries were estimated at 75% for zinc, 87% for silver, 80% for lead, and 55% for gold. The RMV ($/mt) equals $237.

The equation used in calculating RMV for a deposit is:

$$\sum_{I=1}^{n} GiRiSiVi,$$

where

Gi = mill feed grade of commodity I,
Ri = mill recovery of commodity I,
Si = smelter recovery of commodity I,
Vi = $/unit of commodity I,
and n = total number of commodities.

The calculations are shown in the worksheet below.

CALCULATION OF RECOVERABLE METAL VALUE						
Commodity	Grade (decimal)	Mill recovery (decimal)	Smelter recovery (decimal)	Unit	Price	RMV
	Gi	Ri	Si		Vi	(GiRiSiVi)
Zinc	0.11	0.90	0.75	mt	$1,420	$107
Silver	396.5	0.85	0.87	g	$0.30	88
Lead	0.03	0.81	0.80	mt	$1,120	25
Gold	3.6	0.71	0.55	g	$12.18	17
TOTAL						$237

How To Use RMV Worksheet

1. Estimate mineable resource size and resource commodity grades to be evaluated.

2. Select appropriate figure (Figures 3 to 12) in the text of the report, then select appropriate graph line representing nearest estimated mineable resource size. Read RMV ($/st or $/lcy) from y-axis. This is the minimum value per short ton or loose cubic yard of mineable resource adjusted for mining recovery, dilution, mill, and smelter recovery required to yield a 15% DCFROR using the mining and milling scenarios described in the report.

3. To translate this value into a gross in place value (GIPV), back calculate value using assumed mill recoveries or pilot testing results if available, and appropriate smelter recoveries. Suggested commodity prices shown in Table B-1 may be used or other prices as desired.

Commodity Prices

Commodity prices provided for individual metals were determined by using an inflation adjusted thirty-year average for the years 1971-2000. Prices for 1971-2000 from various publications were escalated to 2000 dollars using U.S. Department of Commerce Gross National Product implicit price deflators and then averaged. (U.S. Bureau of Mines, 1975, 1980, 1985, 1986, 1993, 1995, U.S. Geological Survey, 2000, 2001)

Ten (1991-2000), twenty (1981-2000), and thirty year (1971-2000) average prices are shown for the commodities of interest. All prices shown in Table B-1 are given in 2000 dollars.

Table B-1. - Ten, twenty, and thirty year average commodity prices (1971-2000)

Commodity	30 YR AVG	20 YR AVG	10 YR AVG	
Copper	$1.44	$1.22	$1.12	lb
Lead	0.53	0.45	0.44	lb
Zinc	0.72	0.67	0.59	lb
Silver	10.44	8.32	5.33	tr oz
Gold	$478.67	$485.91	$376.56	tr oz